Development of a transitioning approach to reduce Surface water volumes in combined sewer systems

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A thesis submitted in partial fulfilment of the requirements of AbertayUniversity for the Degree of Doctor of Philosophy

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DEVELOPMENT OF A TRANSITIONING APPROACH TO REDUCE SURFACE WATER VOLUMES IN COMBINED SEWER SYSTEMS

By

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I certify that this thesis is the true and accurate version of the thesis approved by the examiners.

Signed ………………………………………..… Date…...………………

Director of Studies

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ABSTRACT

The overarching goal of this research is to establish a successful forum for a transition from the existing paradigm of managing wastewater infrastructure to a more sustainable paradigm that achieves a more efficient utilisation of wastewater assets.

A transitioning approach to support a more efficient utilisation of surface water and wastewater assets and infrastructure is proposed and developed. The determined transitioning approach possesses key stages namely developing the arena, developing the agenda, case study, and monitoring. The case study stage investigates a drainage utility identifying their improvement drivers, the removal of surface water through detailed drainage modelling and the financial examination of the costs incurred under the various scenarios conducted.

Understanding the implications of removing/attenuating surface water from the network is improved through obtaining data by detailed drainage modelling. Infoworks software is used to investigate and assess the current and future operational scenarios of a wastewater system operating over one calendar year. Modelling scenarios were conducted removing surface water from selected areas focusing on the volumes requiring pumping and durations of pumping station(s) operation prior to treatment during storm conditions.

The financial implication of removing surface water in combined sewer systems is examined in three main components. Firstly the costs of electricity incurred at the single sewage pumping station (SPS) investigated during the various scenarios modelled require to be addressed. Secondly the costs to retrofit sustainable urban drainage system (SUDS) solutions needs to be identified. Thirdly the implications of removing surface water for the drainage utility at the national level and the potential saving for householder's committing to a surface water disconnection rebate scheme.

When addressed at the macro level i.e., with over 2,100 pumping stations, some operating in sequence and contained within one drainage utility annually treating 315,360 megalitres the significance of the same multiple quantifiable and intangible benefits becomes amplified.

The research aims, objectives and findings are presented to the identified and convened stakeholders. The transitioning approach developed encourages positive discourse between stakeholders. The level of success of the transitioning approach determined is then tested using a quantitative methodology through the completion of questionnaires. From the questionnaires completed the respondents unanimously agreed that surface water flows should be removed as well as reduced from the combined sewer system.

The respondents agreed that the removal of surface water from a typical combined sewer system is justified by applying a transitioning approach focusing on the energy consumption required to pump increased volumes during storm events. This response is significant based upon the economic evidence and is contrary to the respondents previous position that finance was their most influencing factor. When provided with other potentially available benefits the respondents were even more supportive of the justification to remove surface water from the combined sewer system.

The combined findings of the work presented in this thesis provide further justification that the transitioning approach applied to the removal of surface water from a typical combined sewer system, as determined in this research has been successful.

Table of Contents

List of Tables

List of Figures

Glossary of Terms

Baseline Flow - Sewer flow, including infiltration, on days with less than 0.5mm rain

Combined Sewer Overflow (CSO) - A structure to relieve excess flow loading from a sewer

Combined Sewer - Sewer carrying both foul and surface water

Glossary of Acronyms

CSO's - Combined Sewer Overflows

CAPEX - Capital Expenditure

OPEX - Operational Expenditure

WwTW - Wastewater Treatment Works

SPS's - Sewage Pumping Stations

SUDS - Sustainable Urban Drainage Systems

CHAPTER 1 INTRODUCTION

1.1 INTRODUCTION

Urban areas have historically developed utilising combined sewer systems as the main wastewater carrier and the existing paradigm of managing wastewater has been borne out of necessity rather than the ideal (FR/R0011 2013).

As an alternative to constructing large additional underground storage solutions to accommodate more flows through increased urbanisation, innovative ways to deal with foul and surface water flows on the existing combined sewer (Brown, Keath and Wong 2009) system should be investigated and adopted.

The achievable benefits at the local level such as increased carrying capacity, reduction in numbers of manhole flooding incidents and combined sewer overflow (CSO) spills, improved biodiversity and receiving watercourse quality, and reduced consumption of electricity from a wastewater system possessing an individual combined sewer pumping station, may not in itself provide sufficient justification to substantiate national policy changing strategies.

However these same principles when applied across the drainage utility and seen at the national level when operating several hundreds or even thousands of pumping stations, many operating in sequence the findings may prove to be of greater significance.

1.2 SCOPE OF THE THESIS

The scope of the thesis is to achieve the research aims and objectives by presenting stages to identify, investigate, determine and test a suitable transitioning approach.

The transition under investigation is from the previously accepted practice of wastewater transportation and existing paradigm to a more sustainable paradigm that achieves a more effective and efficient utilisation of wastewater assets.

The main sections are:

- Determination of a suitable Transitioning Approach
- Case Study: Drainage Utility, Detailed Drainage Modelling and Financial Examination
- Testing of the Transitioning Approach

1.3 RESEARCH AIM AND OBJECTIVES

The overarching goal of this research is to establish a successful forum for a transition from the existing paradigm of managing wastewater infrastructure to a more sustainable paradigm that achieves a more efficient utilisation of wastewater assets.

A transition in thinking is needed to greater inform the decision makers of the benefits achievable in the water industry. Improvement drivers which can be realised include increasing the carrying capacity of existing assets and infrastructure, reducing flooding incidents both external and internal and a reduction in energy consumption (Jefferies and Duffy 2011).

The specific aims and objectives are as follows:

Aim 1. Propose a transitioning approach to support a more efficient utilisation of surface water and wastewater assets and infrastructure

Objective 1. Develop a transitioning management approach, identify the key stakeholders (the actors) assess their drivers and how to influence them. Identify and assess the potential benefits and costs for all stakeholders.

Objective 2. Test and establish whether or not the transitioning approach would be successful through communicating and engaging with key stakeholders obtaining their views.

Aim 2. Improve the understanding of the implications of removing/attenuating surface water from the wastewater system.

Objective 3. Obtain data and use modelling software to investigate and assess the current and future operational scenarios of a wastewater system operating over one calendar year. Conduct scenarios removing surface water from selected areas focusing on the volumes requiring pumping and durations of pumping station(s) operation prior to treatment during storm conditions.

Aim 3. Identify and assess the financial implications of the removal/attenuation of surface water from the wastewater system.

Objective 4. Determine the costs of grid electricity incurred at the sewage pumping station (SPS) during the various scenarios modelled.

Objective 5. Investigate and identify the cost to remove all the surface water through a retrofit SUDS project.

Objective 6. Investigate the financial implications of removing surface water for the drainage utility at the national level and the potential saving for householder's committing to a surface water disconnection rebate scheme.

The research hypothesis under investigation is that the removal of surface water from a typical combined sewer system is justified by applying a transitioning approach focusing on the energy consumption required to pump increased volumes during storm events.

1.4 METHODOLOGY

A review of the available literature will be undertaken to provide information to the two fundamentals of the research strategy:

- Transitioning theory with approaches taken to bring about change (Chapter 2.2)
- Examples of successful transition path experiments (Chapter 2.4)

Report writing styles will be investigated and a format adopted. Justification will be identified and provided to the action research approach taken by reviewing various approaches. The action research approach will be written in a qualitative style and was selected incorporating the benefits of a case study in order to achieve the stated aims and objectives (Miles and Huberman 1994).

Transitioning approach methodologies and frameworks such as by Brown, Keath and Wong (2009), Kotter and Rathgeber (2006) and SWITCH Urban Water (2013) will be investigated and developed. Key stages of the transitioning approach determined will be completed obtaining information to support or challenge the research hypothesis (Chapter 3.3.1).

A number of drainage software packages will be investigated to improve the understanding of the implications of removing/attenuating surface water from the combined sewer system. The detailed drainage modelling software package Infoworks will be utilised to conduct current and future operational scenarios of removing surface water during storm events over a calendar year from selected areas.

Data obtained will focus on the volumes requiring pumping and durations of pumping station(s) operation prior to treatment during storm conditions (Chapter 3.6).

The financial examination stage of the research will address the potential savings in electricity consumption at the SPS (Chapter 3.7). This will be calculated utilising the information on volumes and duration of pumping station operation obtained in the detailed drainage modelling chapter and applying a net present value equation.

The costs required to retrofit a SUDS solution will be calculated using a variety of currently available industry wide products, whole life costing tools such as the Water Environment Research Foundation (WERF), Best Management Practice (BMP), and Low Impact Development (LID), cost model's (WERF 2010) and SUDS For Roads, and the construction cost handbook CESMM3 (2011), Carbon and Price Book (CESMM3 2011).

Local to national considerations will be investigated focusing on 2,100 SPS's many of which are larger than the SPS under investigation. With a focus on surface water disconnection rebates schemes operating by drainage utilities across the UK primarily as a result of the Pitt review report (2008) (Chapter 3.7).

Testing the level of success of the transitioning approach determined will utilise a quantitative methodology. The research findings will be presented to the convened meeting attendees and a questionnaire approach taken to obtain responses (Saunders, Lewis and Thornhill 2012). These responses will then be tabulated (Chapter 9.4) to provide information to support or challenge the research hypothesis.

1.5 STRUCTURE OF THE THESIS

The thesis is presented in twelve chapters, the content and purpose of each of these chapters is described below.

1.5.1 Introduction – Chapter 1

This chapter describes the introduction to the research providing the scope and structure of the thesis, the research aim, objectives and methodology and the key conclusions.

1.5.2 Literature Review – Chapter 2

Chapter 2 provides a context for the research and will describe the literature which has been reviewed. This provides information and evidence to both achieve the research objectives and justify the research aims.

1.5.3 Methodology – Chapter 3

This chapter will describe the research methods selected, transitioning approach framework developed, modelling software utilised and financial analysis undertaken to achieve the research aims and objectives.

1.5.4 Development Of A Transitioning Approach – Chapter 4

This chapter will describe the development of the transition arena and transition agenda which is the primary and secondary stages of the transitioning approach framework (Chapter 3.3.2). The main intent of this Chapter is to identify, organise and facilitate key stakeholders; to identify techniques to influence key stakeholders and to distinguish key stakeholder drivers as per objective 1 to achieve research aim 1.

1.5.5 Case Study: A Drainage Utility – Chapter 5

This chapter will describe the development of the transition arena and the transition agenda as applied in a case study to a specific drainage utility. The identification of the key stakeholders and their drivers will be undertaken as per objective 1 to achieve research aim 1.

1.5.6 Case Study: Detailed Drainage Modelling – Chapter 6

This chapter will describe the detailed drainage modelling scenarios conducted in the case study stage to investigate the removal and reduction of surface water flows in the combined sewer system. The information obtained on volumes and durations of pumping station operation will achieve objective 3 and research aim 2.

1.5.7 Case Study: Financial Examination – Chapter 7

This chapter will describe the financial examination conducted in the case study stage of removing and attenuating surface water flows from the combined sewer system. The information obtained on grid electricity costs and potential savings, estimated SUDS retrofit costs, the significance of pumping in sequence, local and national level impacts will achieve objectives 4, 5 and 6 and research aim 3.

1.5.8 Monitoring – Chapter 8

This chapter will describe the monitoring stage of the proposed transitioning approach whose purpose is in process documentation, capacity building, evaluation and learning into the next round of transitioning, supporting objective 1 to achieve research aim 1.

1.5.9 Testing Of The Transitioning Approach – Chapter 9

This chapter will describe the testing of the transitioning approach determined. Utilising the information obtained in the preceding chapters, the research findings were presented to the assembled key stakeholders. Questions were designed to obtain supporting information and justifiable evidence from the attendees. Questionnaires were completed to establish the level of success of the transitioning approach as per objective 2 to achieve research aim 1.

1.5.10 Discussion And Critical Evaluation – Chapter 10

This chapter will discuss and critically evaluate the key stages of the research, identifying the transition approaches and methodologies investigated, utilised and discounted, tasks conducted, results obtained and the conclusions drawn to achieve the overarching goal of the research.

1.5.11 Conclusion – Chapter 11

This chapter will describe the key findings of the research concluding that the removal of surface water from the combined sewer system is justified and further facilitated by utilising a transitioning approach.

1.6 KEY CONCLUSIONS

The research findings described in the following chapters achieves the overarching goal of this research (Chapter 1.3) which is to establish a successful forum for a transition from the existing paradigm of managing wastewater infrastructure to a paradigm that achieves a more efficient utilisation of wastewater assets.

The research aims and objectives have been achieved. Transitioning approach frameworks were identified and developed (Chapter 2.2) to encourage positive discourse between identified stakeholders and actors identifying improvement drivers and intangible benefits.

The determined framework included a case study comprising an investigation into a drainage utility, conducting detailed drainage modelling scenarios and a financial examination (Chapter 4.1).

Testing of the level of success of the approach determined was carried out by delivering presentations on the research aims, objectives and findings, utilising a quantitative methodology approach, completing questionnaires and analysing the responses (Chapter 3.9).

The drainage utility viewed at the national level annually treats 315,360 megalitres and possesses over 2,100 sewage pumping stations with some operating in sequence. The significance of the volumes potentially removed and the benefits achievable, whether monetised or intangible, becomes amplified at this larger scale and the figures involved are more significant and powerful in terms of the justification for such a transition in thinking.

The removal of surface water prior to pumping at the SPS under investigation over the 168 storm events reduced the annual levels of electricity consumption from £265 to £35. This provides an 87% reduction and a potential annual saving of £230 to the drainage utility (Chapter 7.2). The expenditure required to implement SUDS retrofit solutions to deal with the surface water have been estimated in the hundreds of thousands of pounds.

Drainage utilities in the UK offer householders an approx. £50 rebate on their annual bills to disconnect and prevent surface water flows from their property entering the combined sewer system. This reduction will simultaneously achieve improvement drivers and provide intangible benefits. The disconnection rebate programme is not currently promoted by the drainage utility under investigation's preferred method of wastewater charges recovery which is through local councils (Chapter 7.6).

The questionnaire respondents agreed that surface water flows should be both reduced and removed from the combined sewer system (Chapter 9.4.2). All of the respondents to the questionnaire stated that a transition in the operation and utilisation of wastewater assets and infrastructure was required (Chapter 9.4.4).

The removal of surface water response is significant since the economic case is not strong at the single SPS level and the most influential factor was identified as being financial (Chapter 9.4.4). This finding demonstrates important evidence that the transitioning approach determined in this research has been successful.

The research hypothesis of removing surface water flows from combined sewer systems applying a transitioning approach is proven by the questionnaire responses (Chapter 9.4.6). This position is further supported when assessed in conjunction with the improvement drivers and potential benefits achievable (financial, environmental and social).

CHAPTER 2 LITERATURE REVIEW

This chapter will describe the literature which has been reviewed in surface water management to provide evidence to help to achieve the research objectives and justify the research aims.

Typical wastewater systems receive large amounts of surface water during rainfall events and these excess flows have considerable impacts on combined sewers, sewage pumping stations (SPS's) and wastewater treatment works (WwTW) (Butler and Davies 2000).

An improved form and format of communication with decision makers is required, to educate and raise awareness, in order to influence and amend policy and legislation to increase the rate of implementation and installation of retrofit solutions which results in a reduction and attenuation of surface water flows in the combined sewer system (Brown, Farelly and Loorbach 2013).

Transitioning theory and transitioning in surface water management in the water industry will be reviewed and supported by identifying examples of successful national and international surface water transitioning projects.

The potential costs and benefits of removing/attenuating surface water will then be addressed with a focus on the Pitt Review (Pitt 2008) whilst identifying similarities with other utility providers. The intangible benefits of reducing surface water flows whether environmental or social will also be investigated as well as examining the application of applying monetary values.

Detailed drainage modelling applications will be investigated to provide information into the operation and efficiency of the combined sewer system (Ashley et al 2008). The information obtained on the volumes of surface water requiring pumping and durations of pumping station operation under a variety of scenarios will provide appropriate data to perform financial examinations into the cost of electricity incurred.

The literature reviewed here will support the research advancing knowledge in surface water management and justifying the transitioning approach that was investigated, developed, determined and tested.

2.1 BACKGROUND

Over the last twenty to thirty years the environmental agenda has gathered pace and in 1987, the Brundtland Report "Our Common Future" was published (United Nations 1987). This report identified and promoted the transitioning process for "Present and Future Generations" and integrating "Environment and Development" (Karrman 2001).

From the 1980's, some major transformations took place to address primarily as a result of the increased knowledge and understanding of sustainable development (Park 2001), the acceptance of environmental benefits in water resource management and an increased understanding of the potential and real impacts of the wastewater system on receiving watercourses (Chocat et al 2001).

It is widely acknowledged that conventional urban drainage practices contribute to the detriment of the receiving environment and are no longer acceptable (Brown, Keath and Wong 2009). Indeed when there is an inefficient wastewater system leading to detrimental impacts based upon a high proportion of surface water, the potential of a retrofit scheme increases (Swan and Stovin 2007).

With the current understanding of the impacts of climate change (Washington et al 2009) and the increase in population, there is a fundamental requirement for significant investment in long term strategic solutions (Conroy and de Rosa 2011).

The recognition that a transition in thinking is now required is described in the Potschin and Haines-Young report (2011) highlighting that although we depend on the integrity of ecosystems for our well-being, people individually and collectively are one of the main drivers for environmental change.

Across the world, water industry practitioners are faced with common issues such as sufficient and secure water supplies (Reeves 2013), flood protection schemes and ensuring the continuing health of the surrounding environment (Brown and Clarke 2007). It is widely recognised that these factors cannot be fully appreciated nor realised through current urban water management practices (Van der Brugge and Van Raak 2007).

With the spread of urbanisation across our towns and cities (Wright et al 2011) comes an increase in the volume and a shift in the quality of surface water runoff (Stovin, Swan and Moore 2007) which leads to significant detrimental effects on the receiving environment through flooding events and high levels of harmful pollutants (WERF 2010).

2.2 TRANSITIONING THEORY

The future for urban areas requires a visioning process (Milly et al 2008) that optimises the transition from existing wastewater management techniques to those that are more holistically favourable and sustainable (Lienart, Monstadt and Truffer 2006).

Transitioning is the process of moving from one state, style, place or operation into another (Jefferies and Duffy 2011).

Martens and Rotmans (2002) describe a transition "as a set of connected changes which reinforce each other but take place in several different areas, such as technology, the economy, institutions, behaviours, cultures and belief systems". It is also understood that transitions are both inescapable and necessary (Loorbach and Rotmans 2006), and that the principle of learning-by-doing and doing-by-learning are important.

Transitioning processes are apparent in all features and aspects of society (Bergman et al 2008), from transport, technology, communications, to lifestyle choices. Transition pathways can occur through an adaptation of existing practices or through the emergence of innovation technologies and legislation (Jansen 2005).

The question arises as to how a transition might be directed to make it both achievable and affordable (Payne 2009). It is not possible to make a sudden step into the new state since the existing system must operate until such time as new infrastructure and procedures are constructed and implemented and the older more expensive system is no longer needed (Fu, Butler and Khu 2008). In addition, stakeholders' priorities and drivers evolve over time (Reed et al 2009), and this plays an important role in the process of transition.

The foundations for how efficiently operated wastewater systems, using innovative integrated Sustainable Urban Water Management (SUWM), techniques, that satisfy the future vision of sustainable cities, have been previously outlined by Mulder (2007), Messmer, Schultze and Ogurek (2008), Payne (2009), and McLean (2011). The principle of transitioning provides a concept that aims to move towards a 'new world' whereby the infrastructure will be different and have a much lower energy cost of operation with existing techniques. The transition required will incur costs which will produce financial savings (Conlan et al 2009), and social and environmental benefits (Heal, Mclean and D'Arcy (2004).

In addition to the construction of new infrastructure the transition will involve a wide range of stakeholders (DEFRA 2007), including environmental organisations and residents associations (Hottenroth 2008).

Whether the transition is smooth or abrupt is specific to the circumstances involved. In the process of transitioning it is important to identify and tackle specific challenges to transition, the main policies being altered and the barriers in implementing (Brown, Sharp and Ashley 2005), the new technologies (Burke and Litwin 1992).

There are some basic steps to follow to any successful change process. These have been adapted from Kotter and Rathgeber (2006) (Table 1), and characterised by 8 simple steps.

Table 1 Steps To Successful Change (Kotter and Rathgeber 2006)

GENERAL	STEP	TASK
Setting the scene	1. Stress the time for action is now	Demonstrate the requirement for change and the need for acting swiftly
	2. Produce The Change Team	Ensure the change team assembled possesses candidates with the right skills, in leadership, authority, communications, analytical, credibility and with enthusiasm and drive.
Be decisive	3. Define and develop the vision and strategy	Determine what is the vision, how this vision is different and the steps required to achieve it.
Just do it	4. Extensively communicate clear messages	Communicate the message clearly, widely and effectively to ensure as many as possible understand the vision and are onboard with the process to achieving it.
	5. Encourage And Aid Others To Deliver	Identify the blockers and provide solutions in order that the team can progress their individual and collective aims
	6. Identify Achievable Goals	Produce realistic targets readily achievable to encourage satisfaction levels and stimulate further progress
	7. Keep Going	Build upon initial successes by driving harder at each target until all the goals set have been achieved and the vision is achieved
Perseverance	8. Produce a new way	Maintain the innovative approach and techniques in investigation, analysis, design and build, operation and maintenance and ensure they are successful prior to fully replacing the old methods

In 2005, the five year European Union FP6 project SWITCH was established (SWITCH Urban Water 2013). The project was aimed encouraging knowledge transfer of innovative technologies, strategies and new ways of thinking to achieve the urban water vision of the future.

The SWITCH Transition Framework approach (Fig 1), has embodied the principles and further developed the steps identified by Kotter and Rathgeber providing a structure for a city to transform its current urban water management practices into a more sustainable utilisation of wastewater assets and infrastructure suitable for a future vision of communities (Jefferies and Duffy 2011).

This approach, by improving on these key steps and tasks (Table 1), produces a methodology which clearly identifies and outlines the necessary requirements to establish and define the issues.

It involves all of the relevant parties allowing the communication of research and findings to be delivered in an effective environment to bring about the dialogue necessary to influence the decision makers and ultimately accomplish a change in direction or focus towards achieving the identified vision.

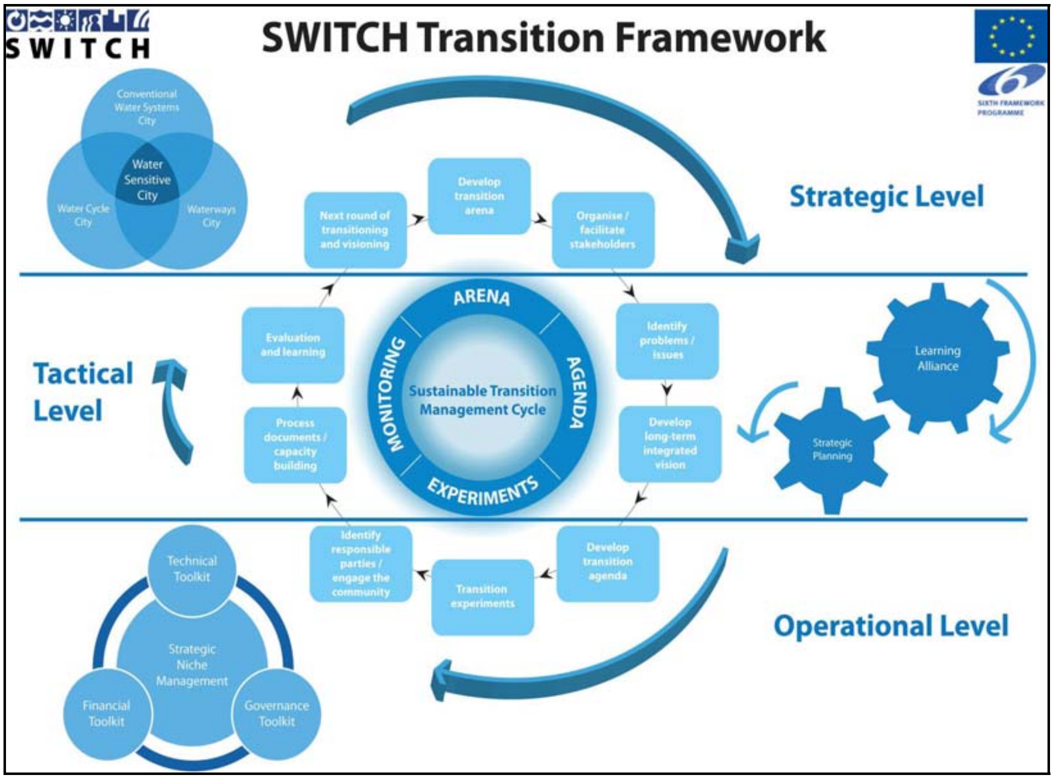

Figure 1 The SWITCH Transition Framework (SWITCH Urban Water 2013)

Setting specific targets and goals is commonly a long term process. The SWITCH ethos through its strategic, tactical and operational levels, aims to quicken the transitioning process to achieve the Water Sensitive City status of the future.

There are three main levels to the Transitioning Framework approach namely Strategic, Tactical and Operational (Fig 1).

Level 1, Strategic – requires the identification of specific targets, setting goals and producing development plans to achieve them.

Level 2, Tactical – involves the investigation, assessment, design and aims of strategic plans to be reviewed and agreed by stakeholders using the Learning Alliance approach.

Level 3, Operational – concerns putting into practice Toolkits developed and enabled through Pilot Studies within the Strategic Niche Management activity.

It is important to recognise these three levels do not exist in exclusivity more so they are interlinked by possessing activities which influence and drive other activities throughout each level (Wittmayer et al 2011). For successful institutional change to occur movement in all three levels is required. Commonly any transitional changes begin with new views on thinking and altering priorities (Brown, Keath and Wong 2008). However to be successful these innovated technologies and practices must be economically viable and environmentally benign.

At the strategic level, the transition arena is not a singular company or structured business nor participants all looking at an issue from the same angle moreover it's a meeting place/environment suitable for a societal network of innovative frontrunners, academics, drainage industry practitioners, sociologists, environmentalists (Frantzeskaki and Rotmans 2010), all possessing individualistic drivers and conflicting objectives (Wittmayer et al 2011), to come together and discuss ideas.

"The way to get good ideas is to get lots of ideas and throw the bad ones away" Linus Pauling, (Bridges 1999).

The successful development of the transition arena is vitally important to the effective communication of historical and present knowledge, research currently being undertaken, new ideas being shared and challenges whether climatic, financial, social etc., being discussed allowing new visions, actions and agendas to be created (Van der Brugge, and Van Raak 2007). Greater influence of stakeholder groups on an organisation's direction, policies and decision management is increasing (Quist and Vergragt 2006).

For example there will be a transition in the way the water companies in England are regulated from 2015, with a step away from the necessity for detailed outputs to a strategy of desired outcomes which are determined via a consumer and stakeholder identification, communication, engagement and management process (UKWIR News 2013).

Within the tactical level the learning alliance is a combination of stakeholders from a variety of disciplines such as academics, non-governmental organisations, government departments, local council authorities, water industry practitioners, and environment agencies amongst others.

By regularly bringing together these stakeholders, through learning alliances (Sutherland et al 2011) through workshops, conferences and meetings, each with their own personal visions, shared visions can be aligned and achieved (Senge 1997).

Stakeholders may agree in the shared vision, however will possess individual improvement drivers. It is important that discussions during all stages of the strategic planning process takes into account the diverse and possibly strongly held and often opposing views from certain stakeholders in order that a clear and strategic way forward is produced (Truffer and Stormer 2009).

Such gatherings of the learning alliance members through meetings, workshops, conferences allows research to be presented, information communicated, visions identified and agreed, policies discussed, challenges faced, actions taken, strategies developed and implemented and monitoring programmes with evaluation and lessons learned in parallel with the four transition management stages.

And at the operational level the transition agenda is further refined and improved. Transition experiments are identified and conducted with interested parties engaged and consulted.

Within strategic niche management are toolkits, technical, financial or governance, which are utilised to support the introduction of sustainable innovations (Mourik and Raven 2006).

These niche experiments such as this research are afforded some initial protection by the engaged stakeholders, to allow the innovative strategy and technologies to be developed (Geels 2005). In some cases compete with and ultimately supersede existing operations thereby successfully completing a sustainable transition (Smith and Raven 2012).

The SWITCH transitioning approach has been applied in four locations, Accra (Ghana), Lodz (Poland), Alexandria (Egypt), and Belo Horizonte (Brazil). Each area possessed individual and differing improvement drivers presenting varying levels of knowledge and understanding of integrated urban water management.

In Accra, the principle concern was to utilise the transitioning approach to assist in mitigating the effects of an ever increasing population. Following the development of the transition arena is recognition by identified decision makers and stakeholders that there was insufficient data to inform decision making. In identifying the problem, there was a decision taken to delay progressing with any transitioning experimentation and instead to focus on basic data gathering exercises first.

The valuable lesson achieved here is that stakeholders now have a greater appreciation of water issues and will give greater consideration to integrated urban water management in their decision making process. Also the experience gained from making these attempts and delaying specific activities in favour of another course of action can be seen as excellent examples of the key components conducted in the monitoring chapter (Chapter 8) and communicated in the next round of transitioning chapter.

In Alexandria, the key driver for transition was that communication and evidence of collaboration between the two distinct authorities responsible for water and wastewater services are challenging. Despite creating the transition arena and developing the transition agenda, the well-established boundaries between the two authorities surfaced with both presenting individual long term visions, future commitments and strategies. This reluctance to work collaboratively and the length of time taken to establish a stable and effective environment for stakeholders to discuss issues (Chapter 4) was deemed an unsuccessful activity and another lesson learnt by the SWITCH representatives.

The City of Lodz already had existing integrated urban water management strategies. The driver for transition was to improve the quality of the urban environment, implement blue-green networks (Chapter 2.6.1) reducing levels of both pollution and flood peak flows in the surrounding rivers. The application of the SWITCH transitioning approach resulted in an increase in stakeholder involvement and community engagement. The principles developed in the transition experimentation stage were deemed successful and the authority responsible for wastewater services wanted to roll out improvement strategies to other river systems. However due to financial constraints this did not occur. The greater involvement by stakeholders in the learning alliance and their increased appetite to implement and progress improvement projects can be seen as a success. The lesson learnt is that despite this increased level of engagement and participation financial considerations remain a deciding factor to any project proceeding.

In Belo Horizonte, the improvement driver was for a more integrated approach between practitioners and researchers. Transitioning towards more sustainable urban drainage practices was already underway. The application of the SWITCH transitioning approach enhanced and improved current strategies and practices by organising and facilitating key stakeholders encouraging greater discourse and collaboration.

Once established the benefits of the learning alliance were utilised to create and provide a link between the research providers, users and decision makers. The work carried out at Belo Horizonte can be viewed as a success and an exemplar site as the location utilised all the levels of the transitioning management cycle (Fig 1), all the ten steps and put into practice many of the outputs from the transitioning experiments.

These locations utilised the SWITCH transitioning approach to assist in achieving their individual improvement drivers with some more successful than others in completing key steps and activities therein. Utilising the three levels of activities demonstrated a progression towards more integrated urban water management (Chapter 3.3.1).

Ultimately the work carried out in these locations can be seen as a success. Despite blockers or new barriers arising, the approach taken is cyclic. By utilising key activities such as process documentation, capacity building, evaluation and learning as part of the monitoring stage the information obtained is then communicated in the next round of transitioning. New key stakeholders and responsible parties will be identified and established to determine a new direction implementing innovative strategies to overcome these blockers and barriers to success.

2.3 TRANSITIONING OF SURFACE WATER MANAGEMENT IN THE WATER INDUSTRY

A transition step faced by every drainage utility is whether to invest significantly in capital expenditure (CAPEX) to save operational expenditure (OPEX) or vice versa (Earwaker and Hannah 2011). In order to move towards the city of the future a paradigm shift is required (Barker and Palmer 2009) with initial capital investment.

This transition may incur capital expenditure which, at the outset, has very little return (Conlan et al 2009) yet once accumulated will produce increasing financial, environmental and social benefits.

Transformation can be seen in the 2002 Scottish Environment Protection Agency (SEPA 2012) report later developed to become the Metropolitan Glasgow Strategic Drainage Plan (MGSDP 2014) and currently being implemented.

This strategy was developed as a driver for transformation in response to the impact of climate change and with significant flooding events and it became clear improved communication was required between all of the main stakeholders (Balmforth et al 2006) to transition away from the current state.

There is increasing recognition that retrofitting sustainable urban drainage systems (SUDS) have the potential to provide a further transitioning step i.e., significant progressive improvement within established urban catchments if it can be properly integrated into urban redevelopment master-planning (Stovin, Swan and Moore 2007).

The drainage utility in Scotland is Scottish Water which has the potential of realising significant benefits through the removal of surface water from its combined sewer systems. Under the Sewerage (Scotland), Act 1968, the drainage utility has a legislative duty (Legislation 2014) to provide sewers to effectively drain its area of domestic sewage, trade effluent and surface water from within the curtilage of domestic and non-domestic premises.

The definition of surface water in the Act is “the run-off of rainwater from roofs and any paved ground surface within the curtilage of premises;”. The Act also provides, under Section 7, for Scottish Water to agree shared ownership of drainage systems with the Roads Authorities.

Surface water discharges are regulated under the Water Environment (Controlled Activities), (Scotland), Regulations 2005 (Scotland.Gov 2005). The traditional operation of wastewater assets and infrastructure in Scotland has been to transport and treat surface water flows in conjunction with foul flows.

Wastewater systems operate on a gravity based system, however many require pumping stations to convey flows from source to treatment. Every pumping station in the drainage utility investigated will consume electricity as its source of energy.

Electricity is the main source of carbon emissions approx 72percent in 2009/10 (Scottish Water 2011), (Fig 2), of which the largest element is from the treatment and transportation of wastewater (Galletti, Kowalski and Poinel 2011).

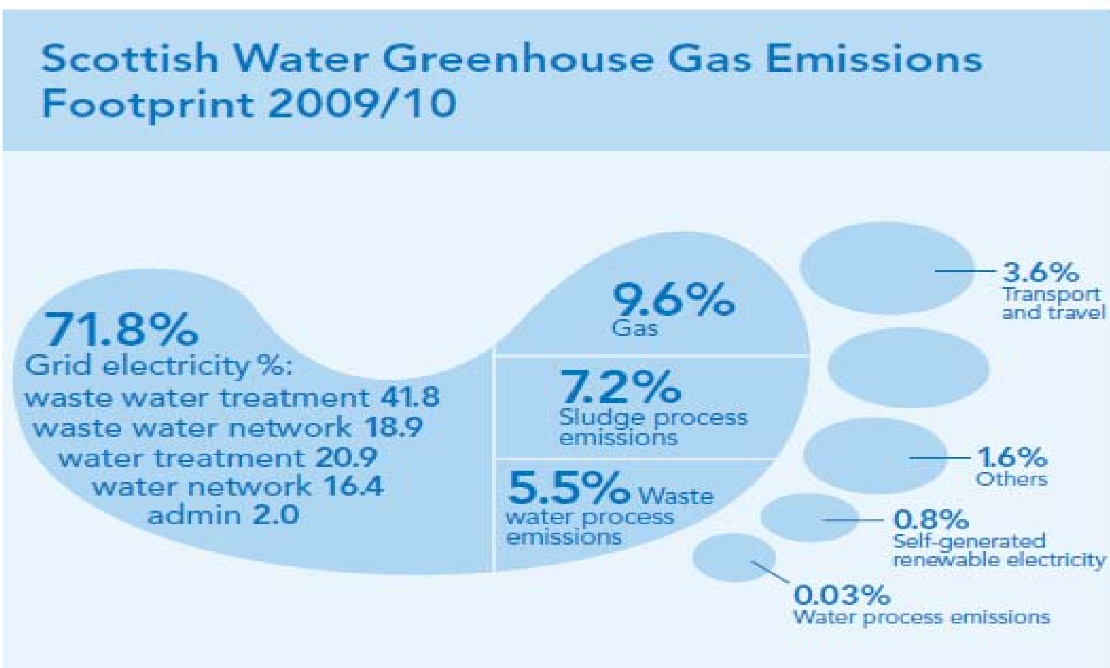

Figure 2 Greenhouse Gas Emissions per Activity for the Drainage Utility, (2009-10) (Scottish Water 2011)

With the drainage utility incurring the single largest organisations power costs in Scotland, approx £40million in 2011, there is a commitment to reduce energy consumption.

There is also a parallel commitment by Scottish Water to reduce the volume of greenhouse gas emissions of which from grid electricity, the wastewater network and treatment accounts for 40% in 2010/11 (Fig 3).

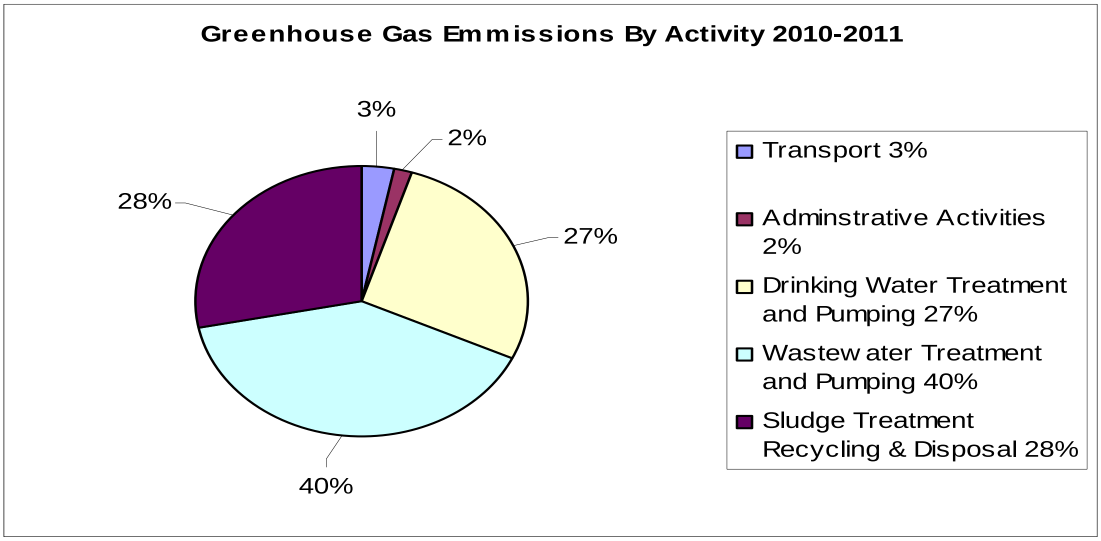

Figure 3 Greenhouse Gas Emissions per Activity of the Drainage Utility (2010-2011), (Scottish Water 2013)

There has already been a positive transitional step whereby all new developments from 1st April 2007 are now required to possess a separate system of drainage (Scottish Water 2014).

This greater focus on surface water is supported by numerous CIRIA publications such as C609 in 2004, C630 in 2006, RP697 in 2004, ICOP in 2004, News Issue 5 – Feb 2004 (CIRIA NEWS 2004a), and Issue 6 – July 2004 (CIRIA NEWS 2004b), which highlight the positive contribution SUDS can have.

The drainage utility has the potential to achieve significant reductions in energy consumption by implementing SUDS removing and/or reducing surface water flows from the operation of its current assets and infrastructure (Chapter 7.3).

The transitioning required now is to remove surface water flows prior to pumping through the implementation of innovative strategies (Chapter 3.3), new ways of thinking and a focus upon differing priorities e.g. reducing energy consumption and climate change as opposed to costly yet swift conveyance.

2.4 SURFACE WATER TRANSITION PATH EXPERIMENTATION

Transition path experimentation is vital in order to:

1. Improve and deepen the understanding of the knowledge base,
2. Build upon previous research and
3. Embed the results in larger innovation networks (Van der Brugge and Rotmans 2006).

There have been some successful examples of transition path experiments towards realising completely separate systems of drainage. The innovative strategies and technologies utilised in other cities serve as a foundation of what can be achieved (Jefferies and Duffy 2011).

2.4.1 Water Sensitive Urban Design

Water sensitive urban design (WSUD) signals a new paradigm that is sensitive to the factors of environmental protection and water sustainability through more effective planning and design of urban environments. WSUD is an opportunity to create beautiful, successful and resilient places (Shaffer 2011).

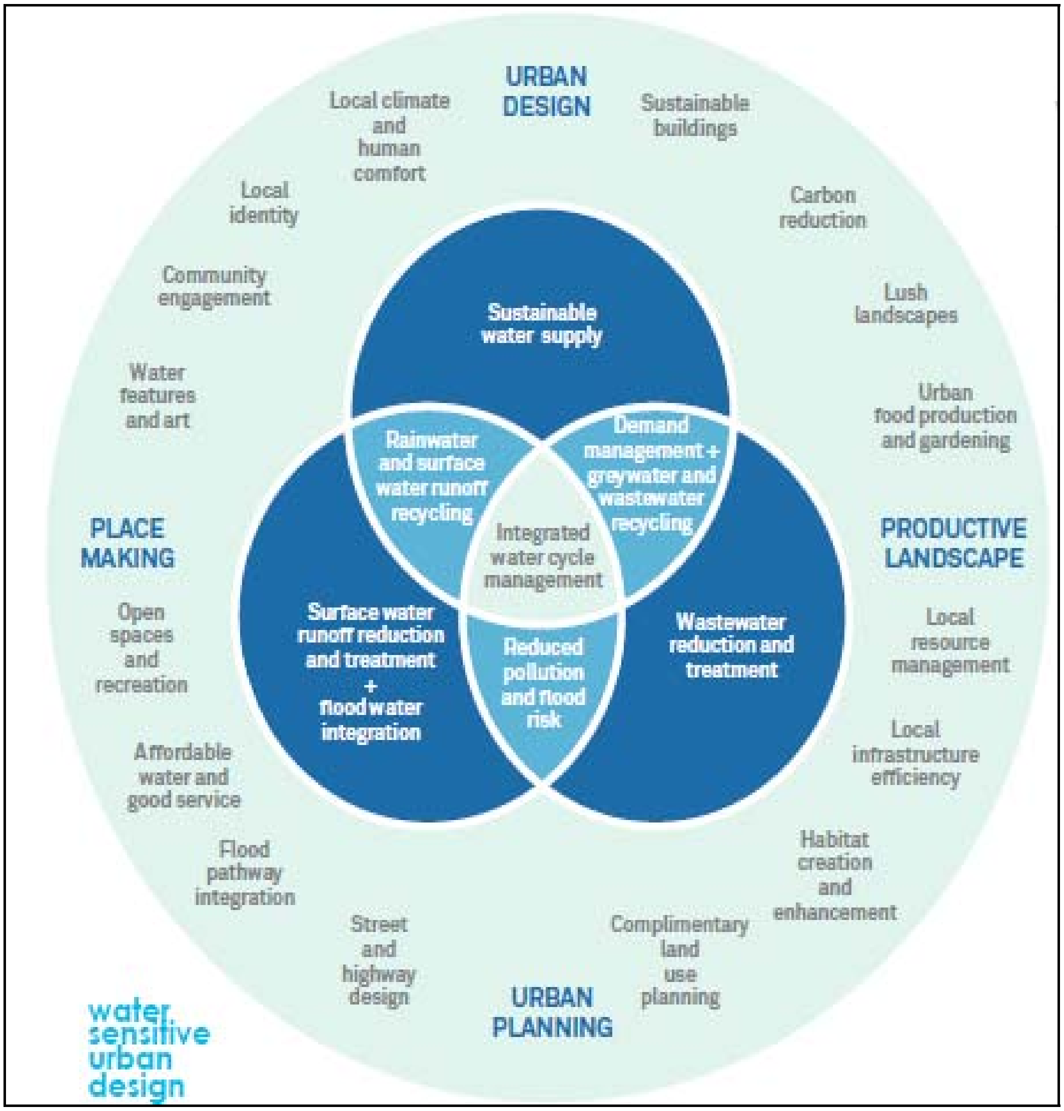

Figure 4 Water Sensitive Urban Design (Morgan 2015)

The approach (Fig 4) demonstrates the complexity faced by various stakeholders and interested personnel in integrating water cycle management with the built environment. There are many aspects of WSUD which utilise key activities described by Kotter and Rathgeber (Table 1) and the SWITCH transitioning framework (Fig 1).

Key stakeholders will be identified, agendas produced and improvement drivers relating to aspects of surface water management will be communicated between the various interested and affected parties. Transitioning frameworks proactively encourage greater communication and where ecosystem service provisions are ‘designed in’ they can help urban areas transition towards more sustainable environments more resilient to changing future conditions (Lundy and Wade 2011).

In Australia, there are encouraging innovations particularly highlighted through the implementation of a Water Sensitive Urban Design (WSUD) programme which has gained international recognition (Melbourne Water 2013). In the South East of Australia, a number of councils are endeavouring to implement the WSUD approach in their municipalities. Following the councils acknowledgement of the importance of stormwater management (Brown, Farelly and Loorbach 2013) and that a transitioning in the operation and utilisation of wastewater assets and infrastructure was required, communication strategies were developed engaging the key stakeholders (Chapter 4.2.1), actors (Chapter 5.2.1) identifying champions and frontrunners (Chapter 4.3.1).

Melbourne’s Water’s Living Rivers Stormwater program in 2011 supplied funding for the second round of WSUD guidelines for councils on the southern and eastern fringe of Melbourne to be progressed and finalised. Guidelines were produced providing information on what is WSUD, why use WSUD, the importance and benefits of implementing WSUD (Grant 2011).

There are a number of other examples of successful surface water management projects in addition to Melbourne including retrospectively installing separate surface water systems, implementing disconnection programmes, retrofitting SUDS and constructing green infrastructure (Stovin 2010) that have achieved significant financial, social and environmental benefits to their stakeholders.

These projects demonstrate a real positive movement along the transitioning process and that change can and will happen with innovative strategies, new ways of thinking and focus upon differing priorities e.g. energy consumption and climate change (Crane et al 2012), as opposed to swift conveyance.

2.4.2 Surface Water Management And Climate Change

Historically the view in the UK and elsewhere around the world was to convey rainwater away as quickly as practically possible (Butler and Davies 2000) mainly using out of sight out of mind underground pipe structures. Although sewer systems in cities, towns and villages collectively are mostly combined an important issue insufficiently addressed is that many of these systems flows require to be pumped prior to treatment (Hammer and Hammer 2008).

Worldwide the theme of sustainability is starting to become an even more important issue whether political or societal in terms of improving and protecting the environment (Chocat et al 2001). The changes in relation to climate, means that there is a direct link between more rainwater and an increase in the flows requiring pumping which inadvertently further exacerbates the onset of climate change (Washington et al 2009).

One of the main impacts of climate change affecting the UK (House of Commons 2009a) is a rise in the rate and seriousness of significant rainfall events (Pitt 2008), meaning the already constrained wastewater assets and infrastructure becomes overloaded (Arthur et al 2009) resulting in an increase in external and internal flooding events (WRc 2009). These unsatisfactory events will continue to occur and indeed increase unless capacity is improved, volumes are reduced and peak flows are attenuated (Foster, Lowe and Winkelman 2011).

The UK Climate Change Act (2009) (Legislation 2008) set targets for cuts of at least 80% by 2050 and 34% by 2020, compared to 1990 levels. Together with the increasing challenges of climate change and pressures on the environment more and more focus is being placed on transitioning approaches for cities in particular (Brown, Keath and Wong 2009).

The paper by Smith et al (2011) utilised the SWITCH transitioning approach (Chapter 2.2) to investigate the relationship between the cost of energy incurred by pumping surface water during storm events and efficient utilisation of wastewater assets and infrastructure (Appendix 1). The investigation into the removal of surface water from the combined sewer system prior to pumping provided useful information to greater understand the financial, environmental and social implications of removing/attenuating surface water flows.

2.4.3 Separate Surface Water Sewer System.

There are many examples of drainage utilities which possess separate foul and surface water systems. The drainage utility for the Emscher Basin in Germany (Villarreal, Semadeni-Davies and Bengtsson 2004) began a 15 year programme to introduce a separate surface water sewer system where possible, aiming to reduce the surface water component in the combined sewer system by 15%. A useful GIS software planning tool was also developed in this project which can identify and illustrate effectively the potential areas suitable for disconnection (Becker et al 2006).

In the UK, all new developments require separate systems of drainage however these only account for a small percentage of the total housing stock, indeed less than one percent (Environment Agency 2007). Therefore a combined strategy of installing SUDS for new developments, retrofitting SUDS for existing sites and or other disconnection programmes requires to be adopted.

The increase in the implementation of SUDS is being widely promoted by environmental agencies across the UK. With an ever-increasing body of evidence the approach has been incorporated by the UK Government's Planning Policy Note 25 (PPG25) and Planning Policy Statement 25 (PPS25) on Development and Flood Risk.

There is a significant opportunity, with the right promotion that SUDS (Stovin and Swan 2007) can be implemented in existing urban areas and achieve substantial benefits. The optimisation of wastewater assets and infrastructure should be addressed in conjunction with the Local Authorities development strategy and the future vision for the community.

2.4.4 Surface Water Downspout Disconnection

An example of a successful transitional programme of water sensitive design towards improving the local environment is in the City of Portland, USA (Mazzotta 2007). The Portland Bureau of Environmental Services (BES), demonstrated a number of key activities and steps as described by Kotter and Rathgeber (Table 1) and the SWITCH transitioning management cycle (Fig 1) to advance the Cities environmental policies. BES identified the key stakeholders ranging from academics, governmental bodies, developers and not for profit organisations to discuss and produce an agenda and vision statement.

The convened and engaged stakeholders produced the Clean River Rewards program identifying a number of improvement drivers providing multiple benefits (Ashley et al 2011) justifying reducing surface water volumes in the combined sewer system (Portlandonline 2015).

The drainage utility offered customers as part of its Clean River Rewards project (Hottenroth 2008), a discount where they can save money and improve the environment by disconnecting their surface water discharges from the combined sewer systems. One of the improvement drivers identified that promoting effective private surface water management practices reduces the operating and maintenance demands on the wastewater assets and infrastructure whilst reducing risk profiles and enhancing the long term financial stability of the drainage utility.

This promotional scheme operated between 1993 and 2011 involved 56,000 homeowners and resulted in 1.3 billion gallons of surface water being removed on an annual basis from the combined sewer system (Portland 2013) with a reduction in local peak combined sewer overflow (CSO) spill volume by 20%.

Having identified the improvement drivers Portland serves as an example of positive transitioning where good communication was vital (Adderley 2007). One of the main goals was to provide the drainage utilities customers with itemised wastewater bills. The detailed information greater informs the customer about the uses of the wastewater management charges (Chapter 7.6).

Providing this information is a positive example of stakeholder engagement and management as described in Brown, Keath and Wong (2009). With successful schemes such as in Portland (Buranen 2009), a lucrative market opened up in the design, manufacture, supply and installation of a wide array of downspout devices (Figs 5 and 6).

Devices range from the standard functional device to the potentially more appealing options (Fig 5). Regardless of which device is installed the principle is the same that the surface water flows which previously entered the sewer system have been now disconnected.

Figure 5 Downspout Disconnection Device (Genova Products 2014)

Similar disconnection programmes have been rolled out in other US Cities such as in the City of Ann Arbour, Maryland (City of Ann Arbor 2007). Surface Water Disconnection programmes result in less surface water being transported and treated producing environmental, social and financial benefits.

A European success story is in the Augustenborg suburb of Malmo, Sweden (Kazmierczak and Carter 2010). By disconnecting the surface water from the combined sewer system (Fig 6) using a combination of SUDS and green roofs there has been a significant reduction in the frequency and volume of flooding events and CSO spills.

Figure 6 Downspout Disconnection In Augustenborg, Malmo (Research Author 2015)

2.4.5 Retrofitting SUDS

CIRIA RP697 (2004) refers to SUDS being considered as Structural and Non Structural. Structural SUDS are physical forms which range from swales, ponds, detention basins, soakaways, and infiltration trenches to green roofs (Stovin 2010). These provide attenuation via retention and varying levels of treatment through both retention and detention, in addition to promotion of biodiversity. Non-structural SUDS are the educational programmes and the increase in exposure to the benefits at all levels from school through to business and the political arena.

It is widely accepted among authorities and professionals that flood management through protection and prevention, with its false sense of security is no longer tenable (Brown, Keath and Wong 2008).

An integral component of any successful transitioning approach is good communication (Chapter 2.2). An example of this can be seen in Tokyo, where substantial lengths of footpath have been retrofitted with permeable paving (Fujita 1997). This large scale retrofit scheme was driven by effective communication due in most part by the enthusiasm and dedication of a single council employee.

There are several examples of successful retrofit SUDS to be found in the UK which possess multiple improvement drivers. The Derbyshire Street Pocket Park Project in Tower Hamlets (Susdrain 2015a) was one such successful retrofit SUDS example which was part of a new cycle route. The project involved improving a dead end residential street by installing rain gardens, attenuating rain planters, small scale green roofs, swales and underground pipes in an area where anti-social behavior was once common.

By linking the street up to another area creating cycle lanes, all surface water naturally drains away and does not enter the combined sewer system. Lessons learned from this successful project were that there are other improvement drivers namely creating a multifunctional space which can also bring about the removal of surface water from the combined sewer system.

An additional successful retrofit SUDS project was in Nottingham (Susdrain 2015b) where raingardens were utilised to manage surface water runoff in a residential area in a pilot scheme to green the areas streets.

Testing the effectiveness of the programme included conducting a questionnaire which produced a number of positive and negative issues. The respondents generally agreed that the rain gardens were successful however 44% would not like to see raingardens established elsewhere in their neighbourhood citing lack of parking or increased hazards for cyclists.

2.4.6 Green Infrastructure

Green infrastructure, as part of a sustainable urban drainage system (SUDS) can have a role to play (Green Infrastructure 2010) in reducing the rate and volume of water entering the wastewater system, providing temporary and permanent storage areas, in carbon storage and sequestration (Foster, Lowe and Winkelman 2011) and allowing the water to infiltrate into the ground.

Successful examples can be found in Philadelphia, Washington DC, California, Seattle and New York (Foster, Lowe and Winkelman 2011). The recently constructed Solaire Building in New York, collects rainfall in a 10,000 gallon tank for use in flushing toilets etc., reducing their potable water consumption by 50% and earned the building the State of New York's first ever tax credit for sustainable construction (PlaNYC 2008).

The twenty year green infrastructure plan in New York announced in 2010 is expected to save upto $2.4billion from the city's sewer maintenance budget over the course of the project. This financial incentive is a prime example of an innovative strategy to aid the city and others along in the process of transitioning (Foster, Lowe and Winkelman 2011).

Examples of where green roofs have been retrofitted are on the increase in Scotland, albeit many are still in the planning and design stage. A recent example of where a green roof has been retrofitted which provides a number of amenities in addition to the improvements to the sewer system is located in Portobello, Edinburgh as seen in Figure 7.

Figure 7 Example Of Multi-Purpose Green Space In Edinburgh (Green Roofs 2011)

Further examples of thriving Green Roof projects in Europe can also be seen in Freiburg and Berlin in Germany and Malmo in Sweden (Green Infrastructure 2010). In Berlin it has been found that the efficiency of photovoltaic cells, used in renewable energy production, is improved when situated on green roofs (Kohler, Wiartalla and Feige 2007).

2.5 POTENTIAL COSTS AND BENEFITS OF REMOVING/ATTENUATING SURFACE WATER

There are a variety of potential costs and benefits of removing/attenuating for all stakeholder's including the Scottish Government, Scottish Water, Water Industry Commissioner for Scotland, SEPA, Consumer Focus Scotland, Householders (customers), and society in general.

There is considerable financial expenditure involved in constructing additional sewer pipes, larger pumping stations, renovating, maintaining and improving existing assets and infrastructure as a direct result of urbanisation and the unnecessary pumping of surface water flows which in itself incurs a considerable expense in energy consumption.

In addition, at any pumping station there are several other factors which contribute to the total cost to the drainage utility, ongoing operational costs include: chemicals, labour, maintenance, spares, contracts, consents, property, consumables, gas, water, telecoms, sludge transport, third party and vehicle costs (Scottish Water 2014).

The retrofitting of sustainable urban drainage systems (SUDS) has been well documented by others such as Stovin and Swan (2007), Atkins (2004), etc., and the financial input required would be based upon one or a combination of the stakeholder's improvement drivers. However any project requires a suitable level of justification in order for a decision to be made to fund the design, construction and maintenance of a retrofit scheme, regardless of size and complexity (Smith and Swan 2012).

The costs for any retrofit solution such as disconnecting for a single property could be significantly reduced if there were to be multiple retrofit schemes and/or disconnections through the economies of scale and competition.

CIRIA has developed a user tool and guidance, W045 BeST (Benefits of SuDS Tool) to support practitioners estimate the impacts that drainage schemes can create. The CIRIA 3045 (2015) range of publications, 3045a,b,c,d provide a comprehensive framework to support the reader in collaborating design and build drainage systems. Evaluating the type and size of these benefits can otherwise be difficult, often requiring specialist economic inputs.

An evaluation tool, CIRIA 3045a has been created to support practitioners identify the benefits of their drainage proposal. The options comparison tool 3045b is utilised to compare more than one drainage proposal. CIRIA 3045c provides technical information behind the guidance. CIRIA 3045d is the user manual which provides an overview on how to use the tool.

Understanding the benefits can support conversations between different stakeholders and support funding applications. When populated the framework will both inform and influence the decision makers, drainage engineers and interested parties. However utilisation of this framework was not progressed due to the date of publication and time limitations of this research.

2.5.1 Pitt Review

Following widespread flooding in 2007, the Pitt Review was commissioned and published in 2008 (House of Commons 2009b). A feature of the report was that the flooding incidents which caused major disruption to transport links, schools, business and other infrastructure were partly due to the high levels of surface water conveyed within the combined sewer system. Another fundamental conclusion identified was that the Water Companies as a whole could provide a more significant role in improving and championing behaviours (WaterUK 2009).

The DEFRA Select Committee highlighted that the current charging mechanism did not promote nor encourage customers to reduce their surface water discharges and advised putting in place a new charging system which would be much clearer, promote disconnection rebate schemes to assist and incentivise customers in installing retrofit SUDS (Environment Agency 2007).

Drainage utilities in England such as Northumbrian Water plc (Northumbrian Water 2013) and Yorkshire Water plc (Yorkshire Water 2013) have now taken on these recommendations and in 2013 publicised on their websites the discounts and benefits available for customers of removing their surface water connections from the combined sewer system.

The findings also reported a recommendation on the requirement for Government to resolve the issue of asset ownership (WaterUK 2009) as this was perceived to be an impediment for widespread uptake and inclusion of SUDS techniques across the UK.

The review went on to detail how similar incentive schemes such as those in Germany had seen a significant rise in the uptake of customers disconnecting their properties surface water discharges, through water reuse, water butts and green roofs and has led to the widespread adoption of SUDS. For example in the North-Rhine Westphalia region of Germany between 1996 and 2004, approx. six million m² of surface area were disconnected (Bennett 2011).

2.5.2 Similarities With Other Utility Providers

The UK Government currently require other utility companies to implement environmental and social improvements schemes as part of their obligations to their consumers. Household energy bills - gas and electricity, contain an 8% levy charge (Fig 8) which is clearly identified on consumers bills (OFGEM 2013).

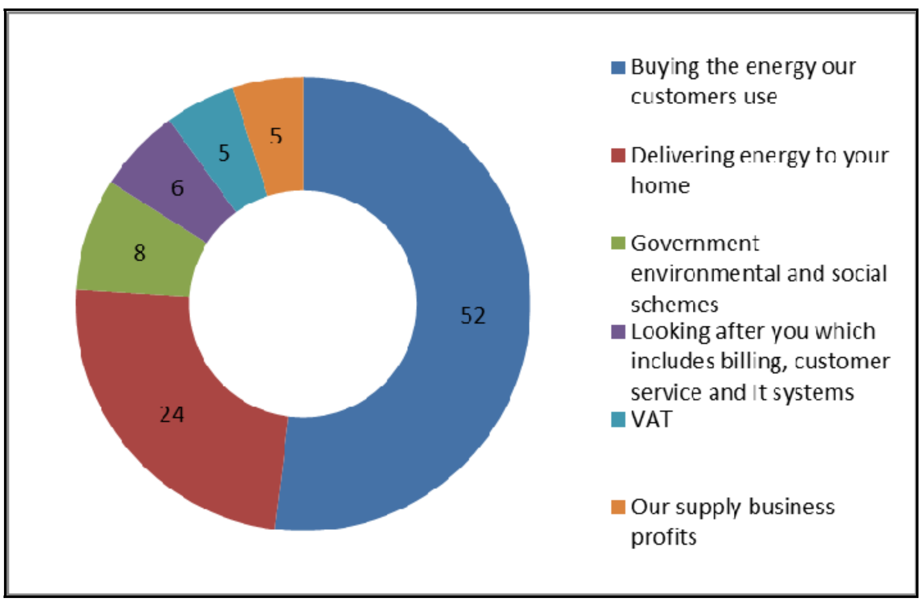

Figure 8 Proportional Representation Of Energy Charges From Scottish Hydro (2013-2014), (Hydro 2013).

The UK Government has promoted similar incentives schemes to the potential surface water disconnection programme in sectors such as the power industry, allowing homeowners to reduce their energy consumption from the electricity grid by the provision of discounts on Solar Panel schemes.

This promotional scheme, once widely communicated saw a proliferation of homeowners installing and companies being established providing the installation services thus benefiting not only the customer but the wider community through employment creation and a greener environment with less reliance on the generation of power from fossil fuels (Gov.uk 2014b).

2.6 INTANGIBLE BENEFITS OF REDUCING SURFACE WATER FLOWS

Environmental and social benefits resulting from the reduction of surface water flows in the combined sewer system can often be seen as interlinked with many unquantifiable and problematic to convert directly into monetary terms and thus intangible, a view supported by the TEEB Case (2010) report.

The appropriate installation and retrofitting of SUDS will however raise the awareness of the numerous environmental and social intangible benefits achievable (Chapter 5.3.2), a view well documented by Semandeni-Davies et al (2007), Stovin, Swan and Moore (2007), Jefferies and Duffy (2007), Cashman (2008), Ashley et al (2011) and others.

The research did not examine in detail the financial implications of the potential intangible benefits due to limitations of the research scope and timeframe.

2.6.1 Environmental

The environmental benefits of removing surface water flows are wide ranging. Designing and implementing blue/green public areas incorporating SUDS will create and enhance habitats (SEPA 2000a).

Involving SUDS ponds particularly located near existing wetland and freshwater habitats and agricultural landscapes will support and enhance a high proportion of biodiversity, possess the ability to colonise quickly, moving between sites by flight, wind and flood water creating wildlife corridors thus providing greater value as habitat sites than isolated areas (Biggs 2011).

The design of SUDS ponds were historically understood to require varying water depths in order to maximise wildlife diversity and bigger was better however it is now understood it is more beneficial to create a mosaic of water bodies of varying depths and degrees of permanence to maximise diversity and that even small water bodies can support valuable species (SEPA 2000b).

Diverting surface water from entering the combined sewer system and channelling the flows reduces the frequency and volume of discharges to the receiving watercourse and increases the volumes of groundwater recharge as roads, roofs and car parks, driveways, and other impervious surfaces no longer allow rainfall to soak into the ground (City of Cambridge 2006).

Pollutant removal (City of Cambridge 2006) will improve water quality and the increased protection in the receiving watercourse morphology as a result whether rivers, estuaries or coastal waters and the surrounding habitat will impact on a large number of uses ranging from abstractions for drinking water treatment, industrial and agricultural purposes to informal recreation.

The Georgia Conservancy highlighted the issue the historical impacts of both point and nonpoint sources of pollution with that runoff from agriculture and development areas were contributing large quantities of nutrients, sediments and toxins to Georgia’s rivers.

This resulted in many of the rivers and streams failing to comply with their designated use whether for recreation, fishing or other purposes whilst adding a number of fish and mussel species to the federal endangered and threatened species list as a result of sedimentation, construction of impoundments and other stresses (Georgia Conservancy 2007).

2.6.2 Social

The social benefits are similarly wide ranging involving increases and reductions respectively. Improving public health through increasing water quality in the receiving watercourse increasing space for amenity, recreation and leisure activities whether rivers, estuaries or coastal waters and the surrounding habitat will have a positive impact on a large number of users, including motorised and pleasure boaters, canoeists, bathers, anglers, shellfisheries and for commercial and recreational fisheries (City of Cambridge 2006).

The overarching goal of this research is supported by the project The Derbyshire Street Pocket Park project as reported by Susdrain (2015a) and recently completed in the London Borough of Tower Hamlets (Chapter 2.4.5). The aim of the project was to provide a useable and sustainable space in an attempt to resurrect a dead end street which suffered from fly tipping and where anti-social behaviour was common.

By utilising permeable paving, small scale green roofs and attenuating rain planters all of the surface water flows were disconnected from the combined sewer system and successfully managed on site. This regeneration project demonstrated what can be achieved in urban areas turning around a neglected area of land into a multi-purpose space with support from the key stakeholders, actors, and champions (Chapter 5.2).

By installing green roofs as part of a surface water removal and/or attenuation scheme will lessen and prevent against the urban heat island effect. In addition to reducing the buildings energy use mitigating against the impact of climate change, increasing biodiversity, improving air and water quality, improving amenity space, visual impact and reducing air and noise pollution and sound transfer (Green Roofs 2011).

Public perception and amenity value surveys carried out on residents close to SUDS ponds in 2000 (Apostolaki 2009) and again in 2010 in Scotland for example (Quek et al 2011) demonstrated a transition in priorities with more residents placing a greater importance and appreciation of the benefits of SUDS over time and exposure to them.

The provision of a pond for example will provide the local residents with an added amenity value. Public perception of the link between well designed and managed SUDS and property values (Apostolaki 2009) appears to have a positive impact on the values of property, with an understanding that properties near well-established ponds would command a 10% premium in addition to an increase in saleability.

It has been identified (Heal, Mclean and D'Arcy 2004) that the local people will frequently suggest establishing picnic areas with benches etc., around ponds in order to further improve the amenity of the area. With an improved recreational value and landscaping a more positive sense of well-being can be created.

Sewer flooding whether internal or external (Cashman 2008) will affect individuals, authorities and the economy. A reduction in these incidents will improve the level of service to the drainage utility's households (customers) and issues relating to public health. The drainage utility has allocated £45million over the next 5 years to address 400 external sewer flooding incidents alone (Scottish Water 2014).

The impact of extreme rainfall events with current wastewater assets and infrastructure will inevitably result in flooding incidents (Balmforth et al 2006). However, the emotional impact and the severe consequences brought about by the effects of flooding on households (customers) should not be underestimated.

2.6.3 Applying Monetary Values

Under investigation in this research is the reduction in levels of energy consumption which is potentially achievable due to the inefficient conveyance of pumping surface water flows to treatment to support the development and determination of a suitably successful transitioning approach.

The potential environmental and societal benefits, many itemised above are challenging to quantify, apply a monetary value and would require considerable further investigation to determine specific financial savings. However these should not be regarded as any less important than monetary values and may be crucial to the decision making process (Casal-Campos et al 2015).

Decision Support Tools (DST's) have been developed to undertake cost benefit analysis of removing surface water runoff from the combined sewer system. DST and cost benefit analysis allows the prioritisation and identification of retrofitting opportunities. DST's to retrofit SUDS assist the user to identify suitable locations which are uncomplicated, cost effective and present hydraulically effective solutions (Stovin and Swan 2007).

Principally the tool with readily understood flowcharts and spreadsheets provides the user with guidance on the cheapest solution whether to use source controls before off-site controls, infiltration systems as opposed to conventional solutions and investigating institutional roofs before residential roofs.

This research has identified a variety of methodologies such as cost benefit analysis and multi criteria analysis which can be applied to determine a monetary and equivalent valuation on aspects of natural capital such as utilised by Yorkshire Water and reported in the Environmental Leader (2014).

A cost benefit analysis of implementing SUDS has also been produced for a site in Harrow Way, Kent by Petrova (2011) to ascertain the costs and benefits of a SUDS programme. This methodology was not selected for use and progression as it was not directly aligned to the researches aims and objectives of identifying the benefits of a reduction in grid electricity costs at a SPS and the financial differences between the savings achievable versus the upfront expenditure required.

The CIRIA 3045a (2015), BeST Evaluation Tool provides a comprehensive framework for drainage engineers and interested parties to populate which when completed will both inform and influence the decision maker(s). Negative use of the tool is that it will not be able to determine the costs (capital, operational, whole-life) of the drainage scheme amongst other limitations. Further utilisation of this framework was not progressed due to the date of publication, framework complexity and time limitations of this research.

It is important to establish a robust framework for construction costs per unit for the range of potential retrofit SUDS schemes available (Swan and Stovin 2007), (Gordon-Walker, Harle and Naismith 2007) see Chapter 8.

Costs for construction have been established and according to the type of contract utilised can be determined and on-going maintenance levels and regimes identified and agreed (Spain, 2010). Costs for each SUDS will be site specific. Less certain however is how to determine the monetary benefit for amenity value (Bastien, Arthur and McLoughlin 2011), habitat creation, increased biodiversity etc., (Petrova 2011).

In regards any retrofitting SUDS project there are costs for disconnection and transfer of surface water from the combined sewer system to the selected SUDS scheme (Swan and Stovin 2007).

Cost information can be found in The Water Environment Research Foundation (WERF 2010) or in the UK Water Industry Research repositories such as UKWIR/09/WM/07/13 by Conlan et al (2009), which possesses spreadsheet-based tools assisting practitioners in determining whole-life cost estimates for retention ponds, detention basins, swales, filter drains and permeable pavements relevant to the UK.

Supporting evidence can be seen in studies such as the 2006, Scotland & Northern Ireland Forum For Environmental Research (SNIFFER) (UE3(05)UW5 (2006) report and the CIRIA 3045 range which proposed a generic decision-making methodology for retrofitting SUDS. In addition to the Atkins report (2004) for use in the Scottish Water SUDS Retrofit Research Project which identified applying monetary values to the numerous benefits achievable a complex issue.

Multi-Criteria Analysis can be used as a methodology for qualitative and quantitative assessments to be conducted to overcome determining monetary values to items of natural capital as defined by the World Forum on Natural Capital (World Forum 2014) as the world's stocks of natural assets which include geology, soil, air, water and all living things by applying relative weights, scoring's or ranking's.

In the simplest of cases it may be appropriate to list and describe the benefits achievable termed ecosystem services, ticking a box to indicate that an option satisfies a particular constraint, moreover it will often be beneficial to utilise a more sophisticated technique such as multi criteria analysis (MCA), (Dodgson 2014).

MCA can be used to bring data expressed in units other than money values (TEEB 2011), the use of relative weights for each criterion and specific scoring or ranking of each option into the appraisal process. The research selected to identify, list and describe the achievable benefits did not utilise the MCA method of analysis due to limitations of scope and timeframe.

Advancements into the inclusion of ecosystem services; benefits that humans derive from nature, in decision making processes have been identified such as the 2011 TEEB Manual for Cities. This report discussed the economics of ecosystems and biodiversity detailing a step by step process for practitioners to utilise providing successful current examples of locations worldwide implementing a focus on ecosystem services in urban management policy making decisions (TEEB 2010).

Wade, Jose and Lundy (2012) addressed combining the benefits and functions provided by implementing SUDS with ecosystem service provision from a multi-functional landscape perspective and showed how utilising integrated management approaches will provide necessary and applicable information to construct and deliver an appropriate foundation for ecosystem service assessment and valuation.

Whichever assessment method identifying environmental and social effects and impacts is adopted, it is clear a greater focus on ecosystem services providing more detailed information to the decision makers will assist in achieving a greater equilibrium between developmental and environmental goals (Brown et al 2011).

With the many intangible benefits identified and despite failing to apply a definitive monetary value on each of the improvement drivers (Chapter 5.3.2), this research has demonstrated the principle that there is an economic value applicable to the benefits attainable, albeit unquantifiable.

This principle will assist and provide support in achieving a more efficient utilisation of assets and infrastructure, a view also supported by the TEEB Case report (2010).

2.7 DETAILED DRAINAGE MODELLING

The Department of the Environment in 1974, in partnership with the National Water Council Standing Technical Committee, provided investment into hydraulics research (WaPUG 2002). The objective was to produce and develop an improved computer software package and procedure allowing the analysis of the performance of existing sewer systems to be undertaken and examined.

The Wallingford Storm Sewer modelling package (WASSP) contains a suite of programs (Hydraulic Research Limited 1986) which was widely incorporated and utilised within the UK water industry allowing drainage engineers to prioritise and improve on the traditional design of sewer systems.

This commercially available package has a built-in geographical information system (GIS) and is designed specifically to integrate drainage modelling with asset and strategy planning and was utilised to conduct a basic hydraulic and financial analysis (Ashley et al 2008).

The hydraulic modelling of sewer systems has become an integral tool in the future planning and design of sewer systems (Wallingford 2013). The software package Infoworks is offered by Wallingford and is commonly utilised by drainage industry practitioners see Chapter 6, within the UK water industry (Caledonian Water 2014) and (MWH 2014).

The rainfall data is stochastically generated with Stormpac software (Stormpac 2014) and is based on several parameters mainly including historical rainfall where the software extrapolates a random number of events based on catchment conditions and Standard Average Annual Rainfall (SAAR), (DFT.Gov 2014).

Detailed information produced allows the operation and efficiency of the sewer system to be better understood, with predictions on sewer surcharging, frequencies and volumes of discharge from CSO's to be identified and the basis for designing improvements and upgrading solutions to improve hydraulic constraints and receiving watercourses water quality established.

2.8 OPTIMUM UTILISATION OF WASTEWATER ASSETS AND INFRASTRUCTURE

The optimum utilisation of wastewater assets and infrastructure is a complex issue involving a variety of key stakeholders (Chapter 4.2), improvement drivers (Chapter 5.3) and intangible benefits (Chapter 2.6).

Essential to this way forward it is hypothesised will be achieving a transitioning step to retrofitting SUDS as described by Swan and Stovin (2007) and implementing disconnection programmes as demonstrated by Yorkshire Water (2013). Design, construction and implementation guidelines are currently available for the optimisation and implementation of innovative SUDS in Sewers for Scotland3 (Scottish Water 2015a).

Reducing the flooding risk or improving water quality or one of the many key stakeholders improvement drivers discussed in this research (Chapter 5.3) will not be significantly achieved through the installation of SUDS within new housing developments alone. As identified in Chapter 2.4.3 new developments account for a minor percentage of the housing stock (DEFRA 2007) and further investigation into implementing retrofit SUDS programmes in urban areas is thus required.

Retrofitting SUDS as referred to by Stovin (2010) is regarded as a replacement for or an augmentation of an existing (combined or separate) drainage system. Whilst they may be hydraulically satisfactory, piped or underground SUDS are not capable of providing the wide-ranging benefits (Conlan et al 2009) which above ground systems can especially in built up areas. Indeed the benefits of developing land whether through housing or industry in partnership with a suitable surface water management system will provide a wide variety of positive environmental and social aspects (Ghimire et al 2013).

Swan and Stovin (2007) highlighted the need that once a SUDS pond has been constructed, it will also require an appropriate level of operational expenditure. Two main concepts arise from these studies, namely that priorities for stakeholders alter over time and can be seen in itself as transition, and that the installation and maintenance costs (Chapter 7.3) for each pond are offset by the potential amenity benefits over time.

In the UK there are differing views whether to install piped or sustainable drainage systems (SUDS) (Ashley et al 2011), however substantial positive data, recently produced through the research into retrofitting SUDS, identifies that if a multi-value approach of the improvement drivers achievable are taken in account these opposing views will be brought closer.

Utilising the transitioning approach selected there will also be recognition within departments, organisations and utility service providers that there is an optimum utilisation of assets and infrastructure which can be investigated and achieved through research experimentation.

This approach is supported by Yarrow's reporting into natural flood management promoting innovation and collaboration published in "The Environment" (2014), (Yarrow 2014b) whereby it is not a case of selecting hard engineering or soft engineering solutions, moreover through improved stakeholder engagement adopting a combination of the two strategies to suit individualistic drivers and barriers, to achieve the most appropriate economical environmental and sustainable outcomes for all.

2.9 SUMMARY

Transitioning is apparent in all features and aspects of society (Bergman et al 2008) occurring through an adaptation of existing practices or through the emergence of innovative technologies and legislation (Jansen 2005) and can be seen as the process of moving from one state, style, place or operation into another (Jefferies and Duffy 2011).

The transition required now is to remove surface water flows prior to pumping through the implementation of innovative strategies, new ways of thinking and a focus upon differing priorities i.e. reducing energy consumption as opposed to more costly yet swift conveyance. Examples of successful transition path experiments in cities adopting innovative strategies and technologies; installing separate surface water sewer systems, retrofitting SUDS, green infrastructure etc., (Ashley et al 2011), reducing and ultimately removing surface water flows from the combined sewer system are researched serving as a foundation of what can be achieved.

In addition, they improve and deepen the understanding of the knowledge base, building upon previous research, as embodied by the steps to successful change demonstrated by Kotter and Rathgeber (2006).

There are substantial environmental and societal benefits to be achieved, however the literature has identified and classified these as intangible benefits whereby no monetary value can be readily applied (SNH 2014). Decision support tools (DST's), cost benefit analysis (CBA) and multi criteria analysis (MCA) are all methodologies which have been developed to assist in the decision making process.

The organisation TEEB, The Economics of Ecosystems and Biodiversity (TEEB) provides a series of publications which assist practitioners improving the understanding of the values of ecosystem services and biodiversity by highlighting their economic benefits not only for the benefits achievable today but also for the multiple advantages for the environment and society for future generations a view supported by reports such as by the Scotland's Natural Capital Asset (NCA) Index, (2014), (SNH 2014).

Whether an improvement in water quality of the receiving watercourse increasing space for amenity, recreation, leisure activities, biodiversity or any of the environmental and societal benefits itemised, the current understanding is that because these widespread benefits cannot be monetised, they attract no significant political or local government support in comparison to employment creation for example.

There is however an increasing recognition that a transition in thinking is taking place through increased discussions between economists and political scientists regarding the impact we have on the environment and the ability to adapt processes to bring out a more sustainable balance between our developmental and the receiving environments requirements.

Hydraulic sewer modelling has become an integral tool in the future planning and design of sewer systems (OFWAT 2011). Detailed information can be produced on the operation and efficiency of the sewer system, pumping stations, sewer surcharging and frequency and volumes of CSO discharges (Dublin City 2014).

The data identified can then be utilised for designing solutions improving hydraulic constraints and the water quality in receiving watercourses (Environment Agency 2013).

The optimum utilisation of wastewater assets and infrastructure by implementing integrated urban water management techniques has to be an integral component of the sustainable future vision of communities (Fu, Butler and Khu 2008) and essential to this way forward it is hypothesised will be a transition step to retrofitting SUDS (Swan and Stovin 2007) and implementing disconnection programmes.

The literature reviewed during this research provided a greater insight into the potential costs and benefits of removing/attenuating surface water to be better understood. In addition and following the floods of 2007, the Pitt Report (2008) provided a number of recommendations for implementation by drainage utilities across the UK.

One of the key statements was dubbed the "rain tax" and has since been included in drainage utilities manifestos. Hereby drainage utilities are recommended to provide not only surface water disconnection rebate schemes but also the clear, transparent and readily available information to households (customers) to understand and partake.

It is imperative not to look at the drainage utility in isolation and the literature review has demonstrated that there are similar utility providers faced with similar challenges. This investigation identifies mechanisms which other utility providers have adopted to assist in the environmental agenda such as a green levy on their consumer bills allowing comparisons and contrasts to be examined and completed.

The literature review has provided supporting evidence to justify the necessity of a transitioning approach from the existing paradigm of managing wastewater infrastructure to a more sustainable paradigm that achieves a more efficient utilisation of wastewater assets and infrastructure.

The information identified and adopted provides guidance to the design of the determined transitioning approach and further justification to the overarching goal of the research describing the context for the research.

CHAPTER 3 METHODOLOGY

3.1 INTRODUCTION

This chapter describes the framework developed to achieve the research aims and objectives. Research methods will be discussed and the selected research methodology presented.

A detailed investigation utilising these research methods and methodology will be undertaken to achieve the overarching goal of this research which is to establish a successful forum to transition from the existing paradigm of managing wastewater infrastructure to one that achieves a more efficient utilisation of wastewater assets.

3.2 RESEARCH METHODS

The literature review itself can be seen as a research activity (Easterby-Smith, Thorpe and Lowe 2004). The literature identified two main fundamentals of the research strategy:

- Transitioning theory with approaches taken to bring about change.
- Examples of successful transition path experiments

The research adopts and builds upon the transitioning approaches identified in the literature see Chapter 2.2 and applies it to a drainage utility as described in Chapter 6.

Different Types of Reporting Format

Quantitative and qualitative research reports follow a similar style of report writing (Miles and Huberman 1994):

- Statement of the problem
- Conceptual framework
- Research questions
- Methodology
- Data analysis
- Conclusions
- Discussions

The research will be written in a qualitative style further developing this format by providing a more cyclical ethos interlinking the various stages to the research (Miles and Huberman 1994).

Research Approach Justification

The research approach taken is built upon the information (Fig 9) provided by Gill and Johnson (1997) with further details offered by two approaches to conducting research, the deductive approach and the induction approach as described by Saunders, Lewis and Thornhill (2003). The deductive approach commences with deducing, expressing, and testing the hypothesis (Chapter 1.3) examining the outcome whether or not it has been successful and if necessary to alter the theory depending upon observations. The induction approach is from the opposite direction in that the hypothesis would follow the collection and testing of data.

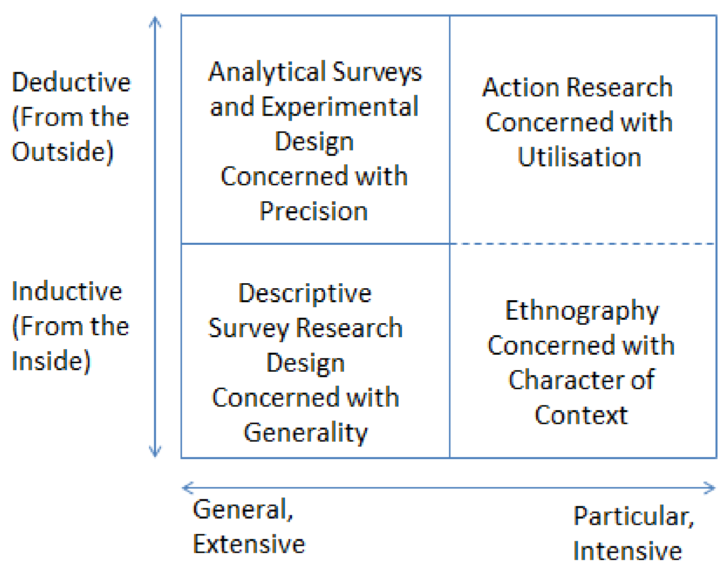

Figure 9 Choosing Research Strategies (Gill and Johnson 1997)

The research approach taken in this thesis is termed action research (Gill and Johnson 1997) in that it combines the principles of both the deductive and the inductive approaches as its primary aim in order to bring about change (Fig 9).

It is shown with a broken line to indicate that it can indeed incorporate the principles of both the deductive and inductive methodologies sometimes at the same time. The inductive approach is taken for this researches overall strategy whilst the deductive approach is selected for the case study component. The ethnography approach was discounted as reports using this approach can be seen to be neither subjective nor objective (Miles and Huberman 1994).

These overall strategies and approaches are not exclusive and can be seen to be interlinked. This interconnectivity is beneficial as it is frequently common for a single research to include and combine quantitative and qualitative assessments and methodology (Table 2).

Table 2 Contrasts Between Qualitative And Quantitative Research (Bryman and Bell 2003)

Quantitative	Qualitative
Numbers	Words
Points of view of researcher	Points of view of participants
Theory testing	Theory emergent
Static	Process
Structured	Unstructured
Generalization	Contextual understanding
Hard, reliable data	Rich, deep data
Macro	Micro
Artificial settings	Natural Settings

There are then a number of different strategies which can be utilised for a research strategy as described by Saunders, Lewis and Thornhill (2012), namely experiments, survey, case study, grounded theory, ethnography, action research, time horizons, cross-sectional and longitudinal studies and exploratory, descriptive and explanatory studies.

Furthermore it is important to recognise that what matters is not the label that is attached to a specific strategy moreover whether the strategy is ideally suited to the researches aims and objectives (Bryman and Bell 2011).

1. Experiments: A strategy seen to be a classical research approach developed mainly in the natural sciences involving defining a hypothesis (Chapter 1.3), selection and measurement of and on a small number of samples.
2. Survey: Commonly associated with the deductive approach and commonly applied to management and business research hypotheses it concerns the collection of a large amount of data from a significant population.
3. Case Study: The data collection techniques utilised within any case study can be multiple including questionnaires, interviews and observations.
4. Grounded Theory: This strategy is proposed as the most suited example of the inductive approach whereby data collection starts without the formation of an initial theoretical framework.
5. Ethnography: originating in anthropology this strategy is generally utilised to explain the social world the research participants occupy in a style where they can understand and view it.
6. Action Research: this strategy commences with an initial idea for a change intervention and can be seen as different from other strategies in regards its attention on action and promoting organisational change.
7. Time Horizons: a strategy commonly utilised in research studies when attempting to observe, monitor and document the systems and influence of alternative procedures within an organisation over a particular duration.

8. Cross-sectional and Longitudinal studies: The cross-sectional application is commonly utilised by research authors in that a significant amount of academic studies concern a snapshot in time. The longitudinal application concerns the alternative approach which possesses the potential to study change and development.
9. Exploratory, Descriptive and Explanatory studies: These multiple approaches are commonly used by researchers where there is more than one purpose to the research.

The action research approach was selected incorporating the benefits of a case study in order to achieve the stated aims and objectives.

The purpose of case study research is to increase knowledge about real events in their context and encapsulate the intricacies and complexities of a single case (Johansson 2003). Case study approaches (Table 3) are determined by the question they are trying to answer whether the study is either descriptive or explanatory (Yin 2012). A case study approach is commonly selected to address situations of how and why things occur in a particular situation (Daymon and Holloway 2003).

Table 3 The Value Of The Case Study As A Research Strategy (Schell 1992).

Relevant Situations for Different research strategies			
Strategy	Form of Research Question	Requires Control over Behavioural Events?	Focuses on Contemporary Events
Experiment	How and Why	Yes	Yes
Survey	Who What, Where, How Many, How Much	No	Yes
Archival Analysis	Who What, Where, How Many, How Much	No	Yes/No
History	How and Why	No	No
Case Study	How and Why	No	Yes

The basic case study entails the detailed and intensive analysis of a single case which may be quantitative, qualitative or both (Bryman 2012), and the most flexible of all research strategies (Schell 1992). Bounded by time and place a case study is commonly associated with a location and able to incorporate different theoretical and methodological frameworks.

Determine the Success of the Research

There are a variety of methods which can be utilised to collect data to determine the level of success of the research. Data can be collected through observation, by using semi-structured and in-depth interviews and by using questionnaires (Saunders, Lewis and Thornhill 2003).

Observation strategy: There are two types of observation method, participant observation and structured observation. Participant observation is qualitative and generally used in social or anthropological studies. Structured observation is quantitative and addresses frequency of action.

Semi-Structured and in-depth interviews: Where the research questions have been developed conducting semi-structured and in-depth interviews are useful tools to collect valid and reliable data. Similarly where the research questions have not been fully developed conducting interviews is a tool to help achieve this.

A questionnaire approach is adopted to test the effectiveness and suitability of the determined transitioning approach. Questionnaires are widely recognised as a simple yet effective tool for collecting data, however the design is by no means simple, especially if the data is to be utilised in further detailed analysis and providing information to support a particular stance, argument or agenda (Easterby-Smith, Thorpe and Lowe 2004).

There are two fundamental issues relating to questionnaire design (Saunders, Lewis and Hornhill 2012), firstly relating to the type of question to differentiate between the facts and expressions of opinion, and secondly to the format of the question, whereby the questions should be kept within similar groupings, be clear and concise and for example, start with simpler factual question(s) before progressing to items of opinions or comment.

There are advantages and disadvantages to the proposed testing of the adopted transitioning approach through conducting meetings and presentations (Oppenheim 1996). By providing the questionnaires at the end of the discussions the success rate in completing the questions is likely to be higher than for example a postal questionnaire. Conducting the questionnaires in this format will be time consuming possessing an always present risk of interviewer bias (Chapter 9.5.1). In addition further skewing of the success of the research findings will result if the questionnaires are only to be completed by personnel from one stakeholder (Rowntree 2000).

The presentation of the statistics obtained will be in a tabular format to display the actual numbers in the sample and converting these figures to percentages (Rowntree 2000) whilst the graphical representation of the results can be referred to in Appendix 2.

The research methods adopted are a combination of approaches, assessment styles and format whose application may be exportable for use with other UK and international drainage utilities.

3.3 RESEARCH METHODOLOGY

The transitional steps to a more optimised and efficient utilisation of wastewater assets and infrastructure will possess recurring stages, plans, milestones, periods of research and reflection, examination, testing and review and can often be seen as cyclical in nature (Jefferies and Duffy 2011).

The research methodology identifies the main fundamentals to the structure of this thesis and describes the first objective which is to develop a successful transitioning approach. A detailed investigation of many of the key activities presented in Chapter 2.2 (Fig 1) will be undertaken and are identified and discussed hereafter as transition management stages.

3.3.1 Transition Management Stages

There are four main stages within the proposed transitioning approach, aim 1 (Fig 1), namely 1. Arena, 2. Agenda, 3. Experiments (Case Study), and 4. Monitoring.

Stage 1, Arena – is where ideas and visions for transition can be discussed and involves the formation of the learning alliance, whose participants possesses the appropriate skill sets to achieve the long term vision (Van der Brugge and Van Raak 2007).

Stage 2, Agenda – concerns the production of an agenda for the learning alliance members which addresses the challenges faced at local and national levels whilst providing appropriate solutions to the way forward (Dodman, McGranahan and Dalal-Clayton 2013).

Stage 3, Experiments (Case Study) – involves building upon previous research, evolving current knowledge and practices, identifying new experiments, utilising innovative techniques, developing and dissemination of findings, by and to members of the learning alliance (Van den Bosch 2010).

In addition to the presentation of the research, additional supporting evidence conducted by academics, industry professionals and bodies, and stakeholder organisations are discussed (Chapter 2.4) to provide greater substantiation and justification of the principles of this research.

Stage 4, Monitoring – involves evaluating the effectiveness of the transition at all stages from inception, through various milestones to completion and the sharing of information along the way to increase knowledge of what went right, what went wrong, what could be better.

3.3.2 How SWITCH Was Adopted And Adapted

The SWITCH Transitioning Framework approach has been adapted and enhanced building upon the literature reviewed and discussed in Chapter 2. With the Sustainable Transitioning Management Cycle (Fig 1) at its core consisting of four transitioning management stages the SWITCH framework may be seen as complex. The framework possesses ten key activities over three levels; strategic, tactical and operational, a strategic niche management section describing SWITCH demonstration projects, a transitioning tools section, a visioning section and a learning alliance which includes a strategic planning section.

The transitioning framework developed in this research (Chapter 4.1) is based upon a rationalisation of the activities contained within the four transition management stages of the Sustainable Transitioning Management Cycle and supported by Kotter and Rathgeber's Steps to Successful Change (Table 1).

The transitioning management stages are entitled Arena, Agenda, Experiments and Monitoring (Chapter 3.3.1) whose first three are utilised as the base stages for this transitioning framework. These stages consisting of ten key activities were investigated for utilisation and potential adoption in this research. The justification behind each key activities inclusion, adaptation, enhancement or exclusion is described in Table 4.

Table 4 Transitioning Activities Adopted, Enhanced, Reduced, Excluded and Utilised.

SWITCH Activity	Reasoning	Further Transitioning Aspect
1. Establish the Transition Arena	Similar to the primary steps as described by Kotter and Rathgeber it is important and ultimately necessary to understand who the stakeholders are and to include this component in any transitioning framework.	Amended the title to Develop the Transition Arena (Chapter 4.2). Absorbed and condensed SWITCH activities 2, 3 and 4. Investigated principles generically. Identified key stakeholders (Chapter 4.2.1). Organise/Facilitate stakeholders (Chapter 4.2.2). Conducted a detailed examination utilising these activities in the Case Study stage (Chapter 5.2).
2. Organise / Facilitate stakeholders	Upon identification of the stakeholders (Chapter 4.2.1) it is vital to organise, arrange suitable environs to facilitate open discussion.	This activity was reduced to a subset of the Develop the Transition Arena stage investigated generically (Chapter 4.2.2). Utilised in the Testing of the Transitioning Approach stage (Chapter 9.1).
3. Identify Problems / Issues	With any transition there will be reasons for improvement whether to resolve a problem, issue or to improve efficiency.	This activity was reduced to a subset of the Develop the Transition Arena stage and investigated generically (Chapter 4.2.2). Upon identification of the key stakeholders (Chapter 5.2) this activity was addressed in the improvement driver's section of the Case Study (Chapter 5.3).
4. Develop Long-term Integrated vision	An integral component of a successful change process is to define and develop the vision and strategy.	This activity is reduced to a subset of the Develop the Transition Agenda stage (Chapter 4.3). The vision is generated with evidence from the literature review (Chapter 2.2).
5. Develop the Transition Agenda	The second of the key stages adopted and utilised in this research. Focusing on how to influence key stakeholders and identify key stakeholder drivers.	Retained the Develop the Transition Agenda title (Chapter 4.1). Addressed generically (Chapter 4.3). Demonstrates the novel approach to the developed transitioning framework (Chapter 4.4). Activities investigated specifically in the Case Study (Chapter 5.3.2).
6. Transition Experiments	Necessary to conduct experiments to provide justifiable scientific evidence to prove and disprove theories.	Activity was adopted, enhanced and utilised as the basis for the Case Study (Chapter 4.1). The focus of the transitioning framework developed investigating a drainage utility, conducting detailed drainage modelling and a financial examination (Chapters 5, 6 and 7).

7. Identify Responsible Parties / Engage the Community	In order to bring about any transitioning process it is vitally important to understand who the responsible stakeholders and parties are (Chapter 4.2.1).	The identification of responsible parties activity was reduced to a subset of the Develop the Transition Arena stage (Chapter 4.2). Key stakeholders were identified generically (Chapter 4.2.1) and specifically (Chapter 5.2). The activity to engage the community was excluded from the novel transitioning framework approach developed in the research (Chapter 4.4).
8. Process Documents / Capacity Building	Important to maintain effective administration and a relevant activity in any transitioning framework (Chapter 8.2).	This activity is reduced to a subset of the fourth key stage, Monitoring (Chapter 4.3). Utilised generically (Chapter 8.2). Excluded from investigation in the case study stage (Chapter 4.1).
9. Evaluation and Learning	With research findings, policies, procedures or recommendations it is important to have a period of review and reflection to understand the justification behind the positives or negatives and learn from them.	This activity is reduced to a subset of the fourth key stage, Monitoring (Chapter 4.3). Utilised generically (Chapter 8.3). Excluded from investigation in the case study stage (Chapter 4.1).
10. Next Round of Transitioning and Visioning	An important component of any transitioning framework is to review, change direction if appropriate and that the transitioning approach is seen as cyclical.	This activity is reduced to a subset of the fourth key stage, Monitoring (Chapter 4.3). Excluded from investigation in the case study stage (Chapter 4.1). Addressed generically due to time and resource limitations of this research (Chapter 8.4).

The concept of and basic structure to the SWITCH transitioning framework namely arena, agenda, experiments and monitoring were adopted for use in this research (Table 4).

Building upon the key principles identified by Kotter and Rathgeber (Table 1), Keith and Wong (Chapter 1.1) and the components of the SWITCH transitioning framework specifically the transition management cycle were then adapted to suit this research.

Following the investigation into the strategic, tactical and operational level stages the majority of activities and components were included and utilised with some activities being discarded or absorbed into others and others being enhanced (Table 4).

At the Strategic level, the visioning aspect of SWITCH for water sensitive cities was explored in the developed transitioning approach (Chapter 4.3) although was not fully described nor discussed in detail in any of the case study chapters specifically.

At the Tactical level, the Learning Alliance and Strategic Planning sections were addressed for information purposes however were not incorporated into the developed transitioning framework nor discussed in greater detail in the case study Chapters.

At the Operational level there is the Strategic Niche Management section. One component is the SWITCH Demonstration projects which were investigated for their level of success and barriers to implementation. Another component was the transitioning tools and specifically a technical toolkit was selected for further investigation and is discussed in detail in Chapter 7.

The developed transitioning framework was adapted and enhanced from the components and activities contained within the SWTICH transitioning framework approach supported by Kotter and Rathgeber's steps to successful change.

3.3.3 Transitioning Aspects Implemented In The Thesis

The literature review addressing transition theory, transitioning frameworks and surface water management provided information and evidence to develop this research's transitioning approach.

Aspects of transitioning theory implemented in this thesis are apparent in the components and activities adapted, enhanced and described in greater detail later in this research. It is important to set the scene, creating a vision and identifying the key stakeholders. This pivotal task is fundamental to all of the transitioning frameworks investigated in the literature review such as described by Kotter and Rathgeber in (Table 1).

The SWITCH transition management cycle contains the majority of aspects which are implemented:

1. Develop the Transition Arena (Chapter 4.2)

2. Develop the Transition Agenda (Chapter 4.3)

3. Experiment Activities, Case Study (Chapter 5, 6 and 7).

4. Monitoring (Chapter 8)

Key stakeholders will be identified, engaged and their improvement drivers determined. Transition path experimentation in surface water management will be investigated and conducted.

The level of success of the transitioning approach framework adapted from the SWITCH Transitioning Framework and enhanced in addition to utilising a Case Study approach will then be tested (Chapter 9).

The transitioning framework developed from reducing, simplifying and reordering the key activities of the SWITCH transitioning framework are fully explored in Chapter 4 and throughout the research.

3.4 DEVELOPMENT OF THE TRANSITIONING APPROACH

This chapter will present the key fundamentals of the transitioning approach framework developed, describing the transition arena and transition agenda stages. This chapter will also introduce the case study contained in Chapters 5, 6, and 7 and the monitoring stage, see Chapter 8.

The transitioning arena stage described in Chapter 4.2 comprises the identification of the key stakeholders as separate from actors and other groups; and the organisation and facilitation of key stakeholders.

The transitioning agenda stage described in Chapter 4.3 involves the identification of the factors influencing the key stakeholders and their individual drivers as separate from Actors and groups.

A detailed investigation utilising these activities will be undertaken to provide further support to the research's ability to successfully determine a suitable transitioning approach and achieve objective 1 and research aim 1.

3.5 CASE STUDY: A DRAINAGE UTILITY

The case study stage will address the implications of the transition arena and transition agenda activities on the drainage utility selected see Chapter 5. A case study approach has been selected based upon the information obtained in Chapter 3.2 (Fig 9).

The investigation will determine who the drainage utilities key stakeholders are and the specific improvement drivers

Case Study – A Drainage Utility:

- Key Stakeholders
- Key Stakeholders Drivers

A detailed investigation utilising these activities will be undertaken to provide further support to the research's ability to successfully determine a suitable transitioning approach and achieve objective 1 and research aim 1.

3.6 CASE STUDY: DETAILED DRAINAGE MODELLING

By utilising hydraulic modelling software as discussed in Chapter 2.7 the case study detailed drainage modelling stage will investigate a typical wastewater system operated by the drainage utility.

This location was identified and utilised due to its key generic components. The wastewater system selected consisted of a system with 100% combined sewers, a wastewater pumping station (SPS), rising main and a Wastewater Treatment Works.

The wastewater pumping station used as the basis of the investigations possesses two pumps operating on a duty/standby arrangement. In addition the case study selected was influenced by model availability and its simplistic nature allows a modeller to perform the scope identified in objective 3 to achieve research aim 2.

To understand the volumes arriving at the pumping station the main modelling scenarios performed are:

1. Run the model to identify the baseline flow
2. Remove surface water flows from Zone A and re-run the model
3. Remove surface water flows from Zone B and re-run the model
4. Repeat the process for the number of zones designated

These scenarios were conducted utilising three modelling criteria over 60min duration:

1. 1 in 1 Year Storm Event (SNIFFER (UE3(05)UW5) 2006)
2. 1 in 30 Year Storm Event (Stovin, Swan and Moore 2007)
3. Typical Year, 168 Storm Events (Stormpac 2014)

Key fixed components were:

1. Pumping station storage based on 2hours at 3Dry Weather Flow (DWF) (Qasim 1998), (SEPA 2002).
2. Simulation criteria based on utilisation of a stochastic process times series rainfall data (1 Year Rainfall) (Hipel and McLeod 1994).

3.6.1 Theoretical Cumulative Modelling Scenario

To further the understanding of the implications of removing/reducing surface water flows as described in objective 3 and necessary to achieve research aim 2, the detailed drainage modelling experiment was then expanded to investigate the theoretical impact of a number of SPS's operating in sequence.

The methodology used is as above and include:

- Use the Case Study catchment as a Baseline Scenario
- Replicate the Case Study catchment and link 8 pumping stations operating in sequence
- Identify the duration of operation of the pumping stations
- Identify the volumes passed forward for two scenarios; 1. Baseline flow and 2. All surface water flows removed.

The theoretical operation for the case study location as shown conceptually in Figure 10 also reflects the current systemic operation of the pumping station regime operating in and around Edinburgh, the capital city of Scotland, Midlothian and East Lothian.

The arrangement of a number of pumping stations operating in sequence transporting flows to treatment can also be found in other drainage utilities (O'Hara 2013).

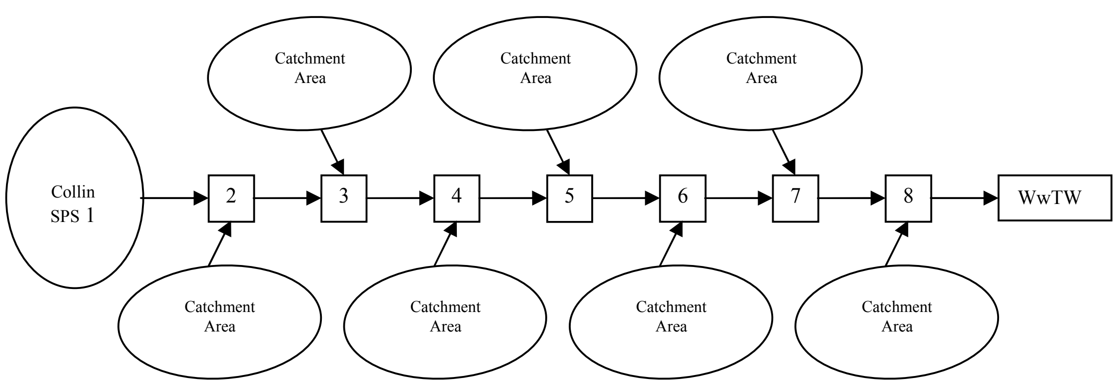

Figure 10 Zones Demonstrating the Hypothetical Sequential Pumping of Surface Water

A number of assumptions were made for each pumping station and were determined to be constant such as; pump size, power rating, wet well dimension, operation, catchment area, length of rising main, static head, friction loss, pipe diameter, pipe roughness.

All of these modelling scenarios will be undertaken in order to produce the volumes in m³ being passed forward and the duration of operation of the pumping station providing sizeable information to support, advise and shape the development of the transitioning approach.

A detailed investigation utilising these activities is undertaken to provide further support to the research's ability to successfully determine a suitable transitioning approach.

3.7 CASE STUDY: FINANCIAL EXAMINATION

The case study financial examination stage will address objective 4, 5 and 6 and research aim 3. This case study approach, see Chapter 3.2, will identify the expenditure involved through the multiple scenarios completed in the detailed drainage modelling stage, for implementing SUDS retrofit solutions, the local to national perspective for a drainage utility operating 2,100 SPS and for UK households (customers), disconnecting surface water flows from the combined sewer system.

Case Study – Financial Examination:

- Detailed Drainage Modelling
- SUDS Retrofit
- Local to National Level
- Households (Customers)

A detailed investigation utilising these activities building upon Chapter 2.7 will be undertaken to provide further support to the research's ability to successfully determine a suitable transitioning approach.

3.7.1 Detailed Drainage Modelling

The pumping station investigated seen at the local level, possesses two pumps operating on a duty/standby arrangement.

The motor rating for the pumps installed is 9KW and are set at 15l/sec. The current price (2010) for electricity negotiated by the drainage utility means the pumping station investigated operates at £0.78KWH.

By modelling the case study drainage catchment the volumes and durations of the pumping station operation will be determined.

This chapter will calculate the grid electricity costs and thus the potential financial saving, identified in monetary and percentile terms, which could be achieved for the scenarios modelled.

The uniform series present worth equation is for calculating Net Present Values, equation (1). In public sector economic appraisals this equation is consistent with the requirements of the NI Practical Guide to the Green Book (DFPNI 2014).

n = 25

i = 3.5%

$$USPW = \frac{(1+i)^n - 1}{i(1+i)^n} \tag{1}$$

The 3.5% real discount rate (Stern 2007) is generally used as the current discount rate in the UK public sector.

3.7.2 SUDS Retrofit

Whilst the volumes of surface water and the energy consumption required during storm events have been identified, the cost of retrofitting SUDS in the case study location requires investigation and determination.

A desktop approach is taken to identify the key components which are required to implement SUDS (Stovin and Swan 2007). A variety of non – SUDS are also under investigation to provide further information to the financial significance of removing the surface water from the combined sewer system.

The systems and solutions investigated will include for:

- Roof Drainage Disconnection: Raingardens and Water Butts
- Road Drainage Disconnection: Swale, Basin, Pipework and Permeable Paving

The financial implications of implementing these key components are investigated and the cost estimates are identified utilising whole life costing tools, a construction cost handbook estimates and a decision support tool. The total cost benefit of retrofitting a variety of solutions will be identified providing the volumes of greenhouse gas emissions (CO_2e) potentially saved per year.

3.7.3 Local To National Level

Upon completion of the financial examination of the research experiment (local level) with reference to larger SPS's, the drainage utility operating 2,100SPS's with an annual bill for grid electricity (national level) is then researched.

Two fundamental areas are investigated:

1. Extrapolation of costs obtained at the local level from the research experiment, to the national level with the drainage utility operating 2,100SPS's many in sequence.
2. Identification of the drainage utilities annual grid electricity bill including:
    - Identification of proportional costs per activity
    - Identification of the percentage cost for the wastewater system
    - Identification of the percentage cost for wastewater treatment

3.7.4 Households (Customers)

Utility companies across the UK such as supplying gas and electricity services provide information and pro-actively promote energy reduction schemes offering financial incentives to increase uptake (Gov.uk 2014a).

In addition to the drainage utility achieving savings through reduced electricity consumption, savings can also be achieved by householders from their annual bills by partaking in surface water disconnection rebate schemes offered by drainage utilities.

In Scotland, the local Council presents and collects the drainage utility's charges. A financial investigation will be conducted on the water charge and wastewater charge information provided by a local Council.

Including:

- Household Charges per Band
- Wastewater Charge per Component

An examination will then be undertaken to identify the number of properties in Scotland, other drainage utilities surface water disconnection rebate schemes and the potential saving for Scottish households of entering a similar surface water disconnection rebate scheme.

3.8 MONITORING

The monitoring stage (Chapter 8) comprises process documentation and capacity building, evaluation and learning, the next round of transitioning and builds upon the literature reviewed in Chapter 2.2.

- Process Documentation and Capacity Building
- Evaluation and Learning
- Next Round of Transitioning

3.9 TESTING OF THE TRANSITIONING APPROACH

The testing of the transitioning approach stage completes the tasks described in objective 2 and necessary to achieve research aim 1.

The interlinking relationship of the transitioning approach methodology (Chapter 4.1) includes the development of the transition arena and agenda, case study (drainage utility, detailed drainage modelling and financial examination), and monitoring with subsequent testing.

The benefits of convening and chairing meetings allowing information to be presented and communicated are described in Chapter 2.2. Meetings are conducted delivering presentations promoting active and open discourse of research and ideas amongst the participants (CIRIA RP697 2004).

These key activities allows the transitioning approach developed to be refined and the case study and its findings to be put under scrutiny, discussed and tested through the use of questionnaires and described in Chapter 9.

It was not practical however to meet, present the research, interview, and obtain completed questionnaires from representatives from all the varying parties. It was decided therefore that a representative sample be taken from the drainage utility since the personnel available for interview would be some of the leading experts in wastewater asset and infrastructure techniques, management and operation. Also it may not have been possible to survey sufficient numbers of personnel within other organisations whose responses would have provided a satisfactory level of comparison for meaningful analysis.

Personnel from the drainage utility were targeted as the sample for investigation whose comments and views would be sought and subject to further analysis.

The sample of staff members engaged included, personnel who had significant experience in wastewater assets and infrastructure, operations, finance, energy, SUDS, commercial acumen, land access and appropriation, legal, environment, planning, government and public relations, management, policy and regulation and were the subset selected to meet, present the research, interview and receive the questionnaire.

The questionnaire will be developed on a quantitative rather than qualitative strategy method as discussed in Chapter 3.2 (Dey 1993). The respondents will be defined as the subset of the sample that actually completed and returned the questionnaire (Bryman and Bell 2011).

The participants will be presented with the research (Appendix 2) and actively encouraged to discuss the positive and negative impacts of the researches principles on their department and the drainage utility which they represent.

A detailed investigation utilising these activities will be undertaken to provide further support to the research's ability to successfully determine a suitable transitioning approach.

3.10 SUMMARY

This chapter describes the methods available and methodologies selected at each key stage of this research to achieve a more optimised and efficient utilisation of wastewater assets and infrastructure.

A variety of research methods were identified and discussed with the qualitative style of reporting format being selected. The action research approach adopted is discussed following the identification of the two formats deductive and inductive.

The contrasts between the different research strategies were highlighted supporting the decision to undertake a case study. The methods utilised to collect data were then addressed presenting the benefits of utilising questionnaires for this research topic.

The literature review allowed the identification of a suitable transitioning approach utilising the fundamentals from Kott and Rathgeber and the SWITCH transitioning approach. The 10 key activities of the SWITCH transitioning management cycle were investigated for potential adoption and enhancement (Chapter 3.3.2).

A detailed investigation of the transitioning aspects implemented in this thesis (Chapter 3.3.3) will be carried out under the headings 1. Develop the Arena, 2. Develop the Agenda, 3. Case Study and 4. Monitoring (Chapter 4.1).

Activities within the development of the arena and the agenda stages will include identifying the key stakeholders, their drivers, organising and facilitating the stakeholders investigating way's to engage and influence them.

The case study stage will concern investigating a drainage utility, performing detailed drainage modelling and a financial examination of the findings.

The drainage utilities improvement drivers will be identified. Modelling scenarios will be conducted on a typical wastewater system possessing the generic components of a combined sewer system and the potential to be utilised as an exemplar site. Data to be obtained will be data on volumes and durations of pumping station operation under a variety of scenarios of removing surface water prior to entering the sewage pumping station.

A comprehensive financial examination on the data obtained from the detailed drainage modelling research experiment will be conducted to determine the electricity consumption costs. Furthermore consideration will be given to the electricity consumption cost of a considerably larger pumping station, the significance of 2,100SPS's many operating in sequence and on the annual costs and potential savings to the drainage utility.

A further detailed financial examination will be conducted into the potential theoretical savings to be obtained by Households by partaking in a drainage utilities surface water disconnection rebate scheme.

In addition to co-ordinating and chairing meetings the research author will provide presentations to the identified key stakeholders on the research aims and objectives completing the process documentation and capacity building activity.

Questionnaires will also be designed and offered to the participants for completion at the culmination of the research presentation to obtain, evaluate and learn information on key stakeholders opinions and views in order to test the level of success of the transitioning approach adopted and put forward by this research.

The completion of these key activities will provide further information and justification to adopt and implement a suitable transitioning approach to achieve a more efficient and effective utilisation of wastewater assets and infrastructure.

CHAPTER 4 DEVELOPMENT OF A TRANSITIONING APPROACH

4.1 INTRODUCTION

This chapter describes the development of a novel transitioning approach to reduce surface water volumes in combined sewer systems. This novel approach is built upon the transitioning approach methodologies identified in Chapter 2.3, adapted and enhanced in Chapter 3.3.2. The transitioning approach developed contains three main areas: Transitioning Approach, Case Study and Testing of the Transitioning Approach (Fig 11).

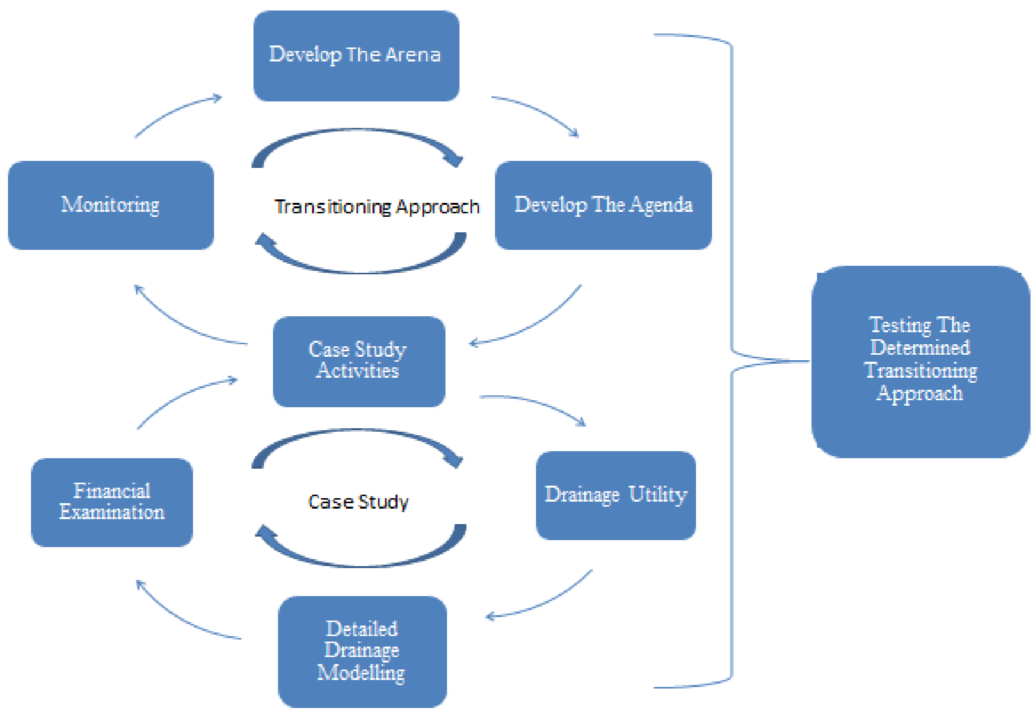

Figure 11 The Research Activities Interlinking Relationships

The key activities to this novel approach are discussed in the following Chapters:

Develop the Transition Arena and Agenda (Chapter 4)

Case Study: Drainage Utility (Chapter 5)

Case Study: Detailed Drainage Modelling (Chapter 6)

Case Study: Financial Examination (Chapter 7)

Monitoring: (Chapter 8)

Testing of the Transitioning Approach: (Chapter 9)

4.2 DEVELOP THE TRANSITION ARENA

This chapter will describe the primary stage of the developed transitioning approach, the transition arena (Fig 12) whose main aim is to identify, organise and facilitate key stakeholders as a separate group from actors, see objective 1 and research aim 1. Those identified should be engaged and encouraged to participate and appropriate environments selected and co-ordinated to ensure maximum discussion between participants.

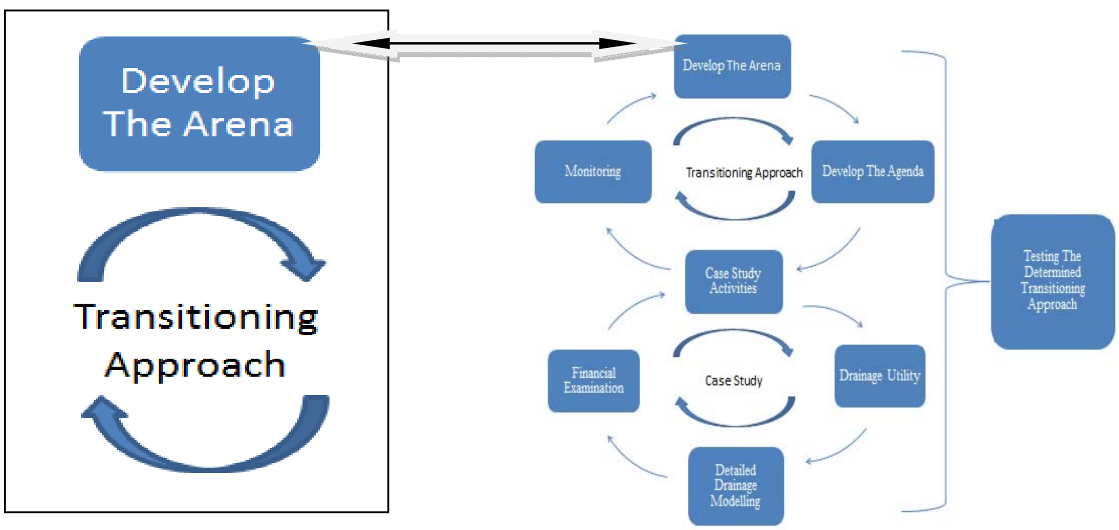

Figure 12 Develop The Arena Stage Of The Transitioning Approach

4.2.1 Identification Of Key Stakeholders

The effective operation of any wastewater system will involve a wide range of stakeholders with varying levels of responsibilities and involvement (SWITCH Urban Water 2013). The key stakeholders in this research are identified and presented in Chapter 5.2.

It is vital to identify the key stakeholders who possess responsibilities and decision making powers and other stakeholders; Actors (Niemcyznowicz 1999) who will represent interested parties who may be able to influence decisions and strategies (Reed et al 2009).

The political arena is a finite one in terms of personnel and future strategies. The cognisance of this is that each elected member is only in post for a particular term of office and can be responsible for one department one day and in a reshuffle responsible for another the next (Michel and Pandya 2009). The conclusion of this is that there will be considerable support for some projects which can deliver short term gains to the detriment of future long term objectives.

By adopting and utilising the proposed transitioning approach outlined by Jefferies and Duffy (2011), incorporating the strategic, tactical and operational levels, key stakeholders can be engaged and targets set.

In addition to the key stakeholders previously discussed there are actors who are individuals, groups, or institutions, which can influence decisions and decision makers and are likely to be affected by a proposed project either positively or negatively (Brown, Farelly and Loorbach 2013).

4.2.2 Organise/Facilitate Stakeholders

With the key stakeholders identified it is vital to organise participants, provide suitable environments and facilities (Acquaye-Baddoo et al 2010). Efficient stakeholder engagement and communication strategies (New Orleans 2014) will encourage regular discourse and sharing of views in an open free environment (Van der Brugge, Rotmans and Loorbach 2005).

By arranging regular meeting's/workshops, organising speakers and presentations, session groups etc., will facilitate the open discourse between all attendees (Scholes and Clutterbuck 1998).

It is important to recognize that decision maker's time is limited when designing workshops, presentations and interviews. In some cases the requirements being proposed will not necessarily bring widespread benefits to a particular unit or team, but when assessed in conjunction with broader ideas such as the organisation's vision statement or agenda then the transitioning steps become more realistic and achievable.

The model of organisation performance and change provided by Burke and Litwin (1992) provides a detailed methodology on how to promote organisations mission statements, cultures and strategies to achieve a greater understanding and sense of inclusion with employees at a local level.

Delivery and presentation of the research aims should focus on the positive aspects of the transitioning idea as opposed to disparaging the ineffectiveness of the current system and operation. The greater the decision maker understands the benefits not only to their organisation but is aware of the advantages and positive feedback from other key stakeholders the more likely the transition will succeed.

Some of the recipients of the research's presentation will have a good understanding of the subject as described in Chapter 2. However a greater number will require extra attention and simplification of the research principles due mainly to their lack of exposure, awareness and knowledge on the topic (University of Washington 2012).

Bringing about policy change will require persistence and a great deal of patience with relationships being developed, nurtured and maintained in order to have any influence on policy changes (Barbu, Groffiths and Morton 2013).

Whilst presenting the outputs from new research experiments and promoting successfully implemented national and international surface water improvement projects, encouraging positive discourse they should always look to identify and support new frontrunners and champions identified in the transition agenda to continue the cycle.

4.2.3 Summary

The transition arena is the first stage of the determined transitioning approach (Chapter 3.4). Central to any successful transitioning approach is the identification of the decision makers, i.e. the key stakeholders, which are characterised as a specific entity from stakeholders/actors whom whilst possessing comparative policies, strategies and aspirations can only influence the actual decision makers.

Organising a suitable arena, facilitating a friendly atmosphere encouraging communication and making participants feel at ease when presenting challenging and innovative ideas and statements allows open discourse and debate.

When organising and facilitating stakeholders, through convening workshops, providing presentations and conducting interviews an important recognition is that every key stakeholder will have their own requirements regarding what it will take to influence them.

The approach taken requires being direct and proactive, focusing on the positive aspects encouraging discourse by delivering thought provoking and open ended questions whilst recognising their time is limited. Focus should be given to high level results and benefits that would contribute to a realistic change whilst the impacts of smaller issues should be conceded (Bryman 2012).

The completion of these key activities provides further information for objective 1 and justification for research aim 1, to adopt and implement a suitable transitioning approach to achieve a more efficient and effective utilisation of wastewater assets and infrastructure.

4.3 DEVELOP THE TRANSITION AGENDA

This chapter describes the second stage of the proposed transitioning approach, the development of the transition agenda whose main purpose is to identify techniques used to influence key stakeholders, see Chapter 3.4, and to distinguish key stakeholders drivers as a separate group distinct from actors (Fig 13).

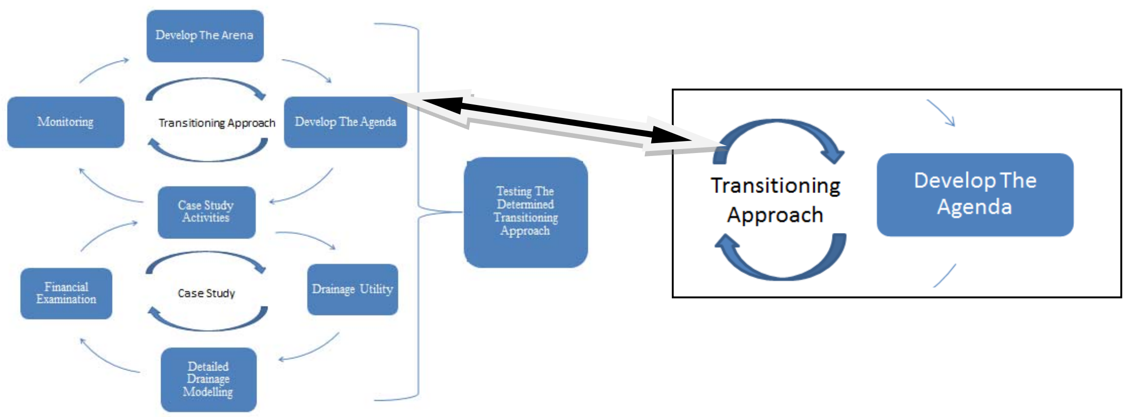

Figure 13 Develop The Agenda Stage Of The Transitioning Approach

4.3.1 Influencing Key Stakeholders

To influence the stakeholder decision makers, greater communication of the advances in innovative technologies, practices and the multiple benefits they can bring and cited in this research is imperative. Key activities include the presentation of current research examples, research knowledge to be further developed, new experiments which can be utilised. New partnerships can then be developed with the formulation of communication strategies, timescales, milestones and project management plans in order to achieve set objectives (Batchelor and Butterworth2 2011).

Each key stakeholder will have their own requirements in regards what it will take to influence them (Chapter 11.6.5), however they will all possess similarities (Scholes and Clutterbuck 1998). Through the items and actions listed below actors can also influence other actors (Sustainable Learning Centre 2012).

Frontrunner

These actors will be creative, visionaries and strategists and will possess the ability influence an official to take action (Brown, Farelly and Loorbach 2013). This approach often from a distance to generate the best results will formally contact actors/key stakeholders through the submission of letters and arranged meetings and or informally through leaflets, chance encounters, conferences, internet websites and accounts (Environmental Leader 2009).

Champions

The effective delivery of any transitioning step will require a Champion who has the ability to successfully communicate the message putting pressure on the decision makers whilst raising the profile of the message within the wider stakeholder group (Lencd 2013).

Beneficiaries

Identify the key beneficiaries of the transition and have them work in partnership with your selected champion when engaging with key stakeholders (Green Facts 2014).

Demonstration sites

Demonstration sites are an effective method to convey the message to key stakeholders in addition to reports, presentations and other literature described in Chapter 2.4, as these are something tangible and real (Todorovic, Jones and Roberts 2008).

Media

The use of multi-media communication tools on the internet such as websites, personal blog's and social media accounts in addition to TV, radio and the press can assist with changing public perceptions influencing the decision-makers thought process and outcomes (De Semir 2014).

Literature

Interesting and ‘eye-catching’ headlines on flyers, brochures, pamphlets etc., are an effective way of delivering key points to a wide ranging audience (USA EA 2014). The frontrunners and champions need to proactively maintain the cluster of interested parties, disentangle ineffective groups, reassemble sub-groups, revisit and refresh transition agendas and visions.

4.3.2 Key Stakeholder Drivers

Improvement drivers will be varied and priority dependent upon the particular stakeholder (Chapter 5.3). Following the key stakeholders and actor’s identification an investigation into and determination of their individual drivers should be undertaken in order to facilitate and develop an agenda into the most appropriate way to influence them.

Each key stakeholder’s organisation will have limited money and resources to devote to new ways of doing things, and the acceptance of an innovative or fresh idea may mean the cancellation or rejection of another department or indeed champions idea (Taylor 2008).

Delivering the same information and key messages to differing stakeholder organisation’s will require additional understanding of the attendees respective agendas, directives and vision statements (Laskowski 2009).

One of the most important aspects of any presentation is to focus on the future as each organisation will have vision statements and or commitments. The likely questions and thus answers needs to be considered prior to the presentation such as how an innovative approach as being put forward by this research will provide benefits to their organisation which would outweigh the costs in the long term (Senge 1997).

Each Actor involved will possess a variety of both similar and differing drivers to the key stakeholders listed in the case study. It is important with any transitioning process to identify the beneficiaries (Green Facts 2014) and those who may be detrimentally affected.

Actors will influence the key stakeholders through three primary routes, namely developing the message, delivering the message and reinforcing the message (Lencd 2013).

4.3.3 Summary

Key drivers influencing each decision maker will be related to financial, political, social and environmental considerations, whilst many possess differing drivers there will be many similarities see Chapter 2.8. This determination allows the agenda to be developed and presented in the most appropriate manner and method to influence them.

By providing the same presentation to different stakeholder organisation's the likely questions and thus potential answers need to be considered prior to the presentation. This will require additional understanding of their respective agendas, directives and vision statements and amendment to suit the audience (Laskowski 2009).

Furthermore through co-ordinating and chairing the initial agenda, delivering the findings of the latest research experiments and subsequent monitoring with post project reviews promotes a greater understanding of the foundation principles and provides information to be debated and discussed.

The positive and negatives of the researches findings can be described and discussed see Chapter 10. An evaluation of the effectiveness of the transition at all stages from inception, through various milestones to completion and the sharing of information along the way to increase knowledge of what went right, what went wrong, what could be better can then be completed.

Stakeholders will possess differing drivers (Ellis et al 2006), and for the development of a successful transitioning approach, the key stakeholders and actors drivers require to be identified and their individual objectives recognised (Hemmati 2010), see Chapter 5.

The completion of these key activities will provide further information for objective 1 and justification for research aim 1, to adopt and implement a suitable transitioning approach to achieve a more efficient and effective utilisation of wastewater assets and infrastructure.

4.4 NOVEL APPROACH

This research is novel (Chapter 1.3) and different to other transitioning theories and approaches investigated in the literature review section as described in Chapter 2.2.

Building upon the literature review and the information obtained in relation to transitioning theory, transitioning frameworks and approaches, this research is novel (Chapter 3.3.2) because it is the first to look at justifying the reduction of surface water flow's in combined sewer systems by conducting these three key tasks specifically;

1. Developing an appropriate transitioning approach to provide a more effective and utilisation of wastewater assets and infrastructure by identifying key stages and requirements.
2. Investigating the levels of grid electricity consumed at sewage pumping stations through conducting detailed drainage modelling and financial examinations, identifying and determining the costs incurred and the benefits achievable.
3. Convening workshops, meetings delivering presentations to obtain evidence from key stakeholders to test the success of the transitioning approach determined and adopted.

CHAPTER 5 CASE STUDY: A DRAINAGE UTILITY

5.1 INTRODUCTION

This chapter describes the first of the key activities of the case study stage of the developed transitioning approach, the development of the transition arena and the transition agenda as applied in a case study to a specific drainage utility (Fig 14). Two tasks will be undertaken namely to identify the key stakeholders and to identify their drivers which will provide further supporting information and justifiable evidence to achieve the research aims.

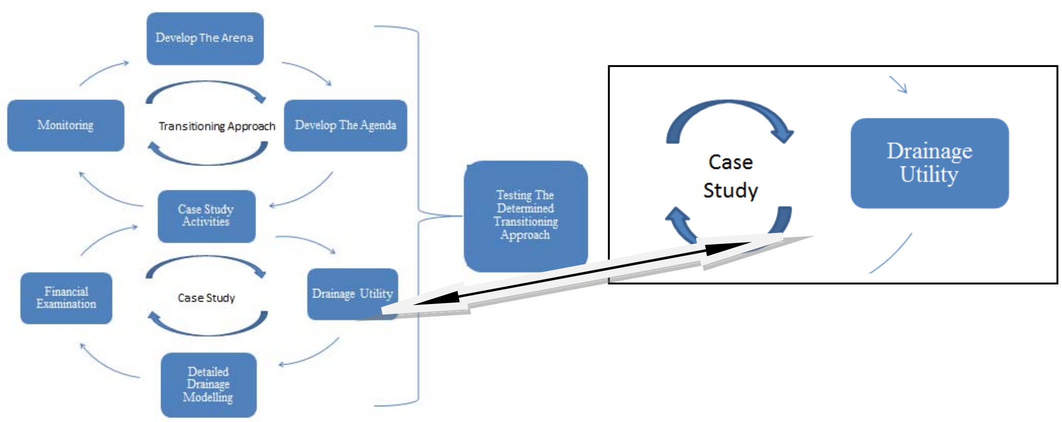

Figure 14 Case Study Stage Investigating A Drainage Utility

5.2 THE KEY STAKEHOLDERS

The Scottish Parliament established a regulatory framework for the water industry in Scotland (Scottish Government 2014a). Scottish Ministers and their officials manage the relationship for Scottish Water and their regulators to operate within the framework.

The Scottish Government identified the key stakeholders (Fig 15) within this framework to be Scottish Water (SW), their economic regulator - the Water Industry Commission for Scotland (WIC), the Drinking Water Quality Regulator (DWQR), the Scottish Environment Protection Agency (SEPA), and the customer representative body - Consumer Focus Scotland (CFS).

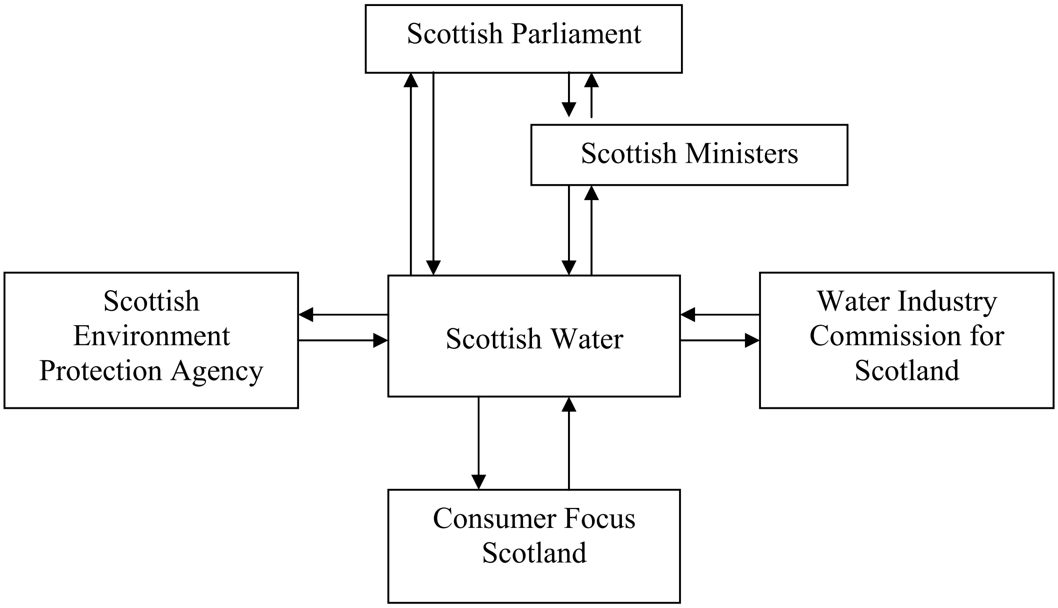

Figure 15 The Identification And Interaction Of the Key Stakeholders In Scotland

For the purposes of this research the Drinking Water Quality Regulator has not been investigated and reported on as the DWQR is mainly concerned with potable water services.

An important concern for all stakeholders is the ability to implement effective strategies to deal with surface water runoff (Faram et al 2010), especially with the increase in urbanisation combined with the implications of climate change (Warwick and Charlesworth 2011), (Green Infrastructure 2010), and (Truffer and Stormer 2009).

5.2.1 Actors

In addition to the Key Stakeholders previously discussed there are Actors who are individuals, groups, or institutions, which can influence decisions and decision makers and are likely to be affected by a proposed project either positively or negatively (Brown, Farelly and Loorbach 2013).

Actors involved in this transitioning process may range from the Academic Community, Local Council Authorities, Convention of Scottish Local Authorities (COSLA), Scottish Enterprise, Landowners, Residents, Champions, Scottish Natural Heritage, Businesses and Community Groups (SWITCH Urban Water 2013), amongst others.

5.3 KEY STAKEHOLDER DRIVERS

Following the key stakeholders and actor's identification a web search investigation into and determination of their individual drivers was undertaken.

5.3.1 The Scottish Government

The Government is a devolved government and is responsible for many of the general concerns of the people of Scotland such as Education, Health, Transport and Justice etc. The objectives of the water industry statutory framework were set by Ministers for the water industry to be delivered at minimum cost to customers (Scottish Government 2014a).

The Ministerial objectives for the water industry are for improvements to:

- The Environment
- Customer Service
- Enable New Connections
- Mitigate and adapt to climate change

5.3.2 Scottish Water

The drainage utility is responsible through the Sewers for Scotland Act, 1968 Chapter 47 (Speirs 2007) to provide wastewater services, transporting and treating nearly 1billion litres of wastewater each day before returning it in a safe manner to the environment (Scottish Water 2014).

The drainage utility aims to reduce capital and operational expenditure, and consumer bills, improve on services, identify future aims, and implement strategies whilst taking cognisance of the regulators, such as the WIC and SEPA.

The role of the Scottish Water Board is to, although not exclusively:

- Provide strategic guidance and direction to Scottish Water
- Demonstrate high standards of corporate governance
- Oversee the delivery of Scottish Water's Regulatory outputs
- Ensure statutory requirements in relation to the use of public funds are complied with.

The drainage utility has established a vision statement to reduce energy consumption through the implementation of innovative technologies to be the lowest carbon operator of water and wastewater services in the UK (Toop 2014).

Scottish Governments Hydro Nation paper (Scottish Government 2014b) requires the drainage utility to reduce its reliance on, and levels of energy consumption whilst identifying, designing, promoting and providing investment to install renewable energy schemes thereby decreasing its greenhouse gas emissions.

It is widely accepted by drainage engineers, academics, environmental agencies and practitioners that there are a number of potential improvement drivers which can be realised through removing surface water from the combined sewer system.

A variety of financial, environmental and social improvement drivers through the removal, reduction and attenuation of surface water flows in the combined sewer system were investigated. Referring to the list of potentially achievable drivers identified below, they can be seen to be far ranging and affect not only the drainage utilities assets and infrastructure but have wider implications affecting the wider society and the environment as a whole.

Financial Drivers –

- Reduction in carbon emissions with the importance on climate change (Semandeni-Davies et al 2007).
- Reduction in CAPEX and OPEX for the drainage utility (Gahan et al 2013).
- Reduction in energy consumption through reduced volumes requiring pumping, transportation and treatment at the wastewater treatment works.
- Increased headroom to support further development (including the ability to absorb the effects of climate change) (Arkell 2010).

Environmental and Social Drivers

- Increased habitat creation (SEPA 2000a), green open spaces improving wildlife corridors (Stovin, Swan and Moore 2007), amenity value (Arthur et al 2009).
- Reduced impact of urbanisation (Stovin and Swan 2007).
- Reduction in sewer flooding risk (both internal and external (Cashman 2008)
- Reduction in Combined Sewer Overflow Discharges (SEPA 2002)
- Environmental quality improvements (FR/CL0005 1996) such as improving public health at Bathing Waters, increased river water quality and greater watercourse morphology protection.

The two potential improvement drivers under investigation in this research is the reduction in levels of energy consumption and greenhouse gas emissions which is potentially achievable due to the inefficient conveyance of pumping surface water flows to treatment to support the development and determination of a suitably successful transitioning approach. The transitioning approach developed allows these drivers to be ascertained however interconnectivity between the identified improvement drivers warrants further examination.

The need to achieve the identified drivers is supported by SEPA's WAT-PS-06-08 paper (2006), which states that "the provision of a sustainable drainage infrastructure is integral to improving and maintaining a good water quality environment.

The Metropolitan Glasgow Strategic Drainage Plan (MGSDP 2014), similarly adopted improvement drivers to this research identifying principles achievable of: 1) Removal of development constraints, 2) Flood risk reduction, 3) Water quality improvement, 4) Habitat improvement and 5) Integrated investment planning. This approach was also in alignment with the overarching goal of this research by communicating, involving and providing a consensus amongst convened stakeholders and stakeholders groups to achieve economic and intangible benefits.

Furthermore and applicable to all drainage utilities is that they will all possess assets and infrastructure which can at best be described as long life and low probability of failure. Reports by the UKWIR publisher provides appropriate classifications such as UKWIR Report Ref No 11/WM13/1, by Conroy and de Rosa (2011), which is supported by the National Urban Waste Water Study, from The Department of the Environment, Heritage and Local Government (National Urban Waste Water Study 2003), which identifies priorities for drainage utilities to invest and commit capital, sometimes significant sums to renew, replace tired and inefficient pipes, pumping stations due to a number of detrimental factors.

Many of the improvement drivers identified and discussed in the National Urban Waste Water study are quantifiable in monetary terms, however many of the improvement drivers applicable to this research concern intangible benefits (Chapter 2.6), which are challenging to quantify and monetise.

This research has discussed throughout that differing stakeholders will possess similar improvement drivers albeit with differing priorities and barriers to success.

5.3.3 Water Industry Commission for Scotland

A requirement of the Commission is for Scottish Water to provide information on its financial, customer service and asset performance (Water Commission 2014). Its aim is to manage an effective regulatory framework to ensure Scottish Water provides a high quality service and value for money to customers.

1. Setting Prices

Having a statutory duty to promote the interests of customers, a key driver for the Commission is to keep customer bills down (Water Commission 2014).

Every five years the Commission sets limits on the prices Scottish Water customers have to pay for their wastewater services, known as Price Reviews.

2. Monitoring and Performance

The Commission uses a variety of mechanisms to challenge Scottish Water to improve in each of the following areas: Investment, Customer Service, Costs and Leakage. The Commission also monitors the drainage utility's performance to ensure that it reacts positively to these challenges. Regulatory data is submitted by the drainage utility to the Commission for review and is published by the WICS annually.

5.3.4 Scottish Environment Protection Agency

SEPA is required to maintain and improve the environment thereby securing its condition for future generations.

Working with other agencies within the UK they are required to comply with the European Community (EC) Bathing Water Directive (EC.Europe 2014), to reduce the risk of urban and rural pollution in our coastal and inland bathing waters (SEPA 2014).

Some of the areas SEPA has a direct role in the water industry implementing directives range from, yet not exclusively include: The Water Framework Directive, Bathing Waters, Shellfish Waters, Nitrates, Freshwater Fisheries, Urban Waste Water Treatment, Exchange of Information on the Quality of Surface Freshwaters and Protection of Groundwater.

SEPA provides information and advises the Ministers (Scottish Government 2014a) on the delivery of and the need for future investments in environmental improvements.

SEPA is also responsible for monitoring discharges from the drainage utility's assets to ensure they meet environment requirements.

5.3.5 Customer Focus Scotland

The CFS campaigns of behalf of consumers in Scotland for improved energy, post, water, digital, legal and many other essential public and private sector services (Consumer Focus Scotland 2014).

The CFS has three main drivers:

1. Research: the CFS obtains data on consumer related matters and consumer views on those issues.
2. Information: the CFS promotes the publication of information and advice to consumers.

3. Representation: the CFS submits proposals, provides information and represents consumer views to Scottish Ministers, the Regulators, European Institutions and any other relevant party.

Scotland's largest water treatment plant at Milngavie was given the approval for a £120million upgrade in 2007 with very little discussion or participation from Scottish Water's customers in the decision making processes. The Customer Forum within the CFS has been set up in collaboration with the drainage utility and the WIC with a view to influencing future decisions. The Forum is Chaired and guided by nine members and in 2014 it is expected to report on customer findings to the WICS for the next price setting period which is 2015-2020.

5.3.6 What Are The Actors drivers

From the literature review conducted the most commonly occurring examples of positive and negative drivers for the actors include:

- Protection of watercourses from pollution and ensuring groundwater recharge
- Financial savings through reduced water bills
- Habitat promotion and improved biodiversity
- Social aspect, creating a focal point for the community
- Policy and Legislation such as the EU Water Framework Directive, 2000 amongst others (EEB 2014).
- Climate Change
- Loss of land for development

- Short term disturbance during construction/retrofitting/disconnection
- Traffic increase
- Increase in visitors
- Poorly or badly designed/constructed SUDS
- On-going maintenance requirements and charges

5.4 SUMMARY

The key activities of the transition arena and transition agenda stages have been applied and undertaken for a specific drainage utility.

The key stakeholders as identified by the Scottish Parliament (Scottish Government 2014a) were the drainage utility Scottish Water (SW), their economic regulator – The Water Industry Commission for Scotland (WIC), the Scottish Environment Protection Agency (SEPA), and the customer representative body Consumer Focus Scotland.

The numerous drivers applicable to the individual stakeholders were identified. The communication of ideas and opinions helps influence the best possible SUDS/disconnection projects to be constructed by taking into account key stakeholder and actors view's (Ashley et al 2008), providing short-to long term benefits such as reduced energy consumption, pollution control, flood management and habitat improvement, operation and treatment costs (Wright et al 2011).

This chapter provides further information and justification to adopt and implement a suitable transitioning approach to achieve a more efficient and effective utilisation of wastewater assets and infrastructure.

CHAPTER 6 CASE STUDY: DETAILED DRAINAGE MODELLING

6.1 INTRODUCTION

This chapter describes the second of the key activities of the case study stage of the proposed transitioning approach investigating through detailed drainage modelling (Fig 16) as discussed in Chapter 2.7 and Chapter 3.7 the removal and reduction of surface water flows in the combined sewer system. The detailed drainage modelling provides further supporting information and justifiable evidence completing objective 3 to achieve research aim 2.

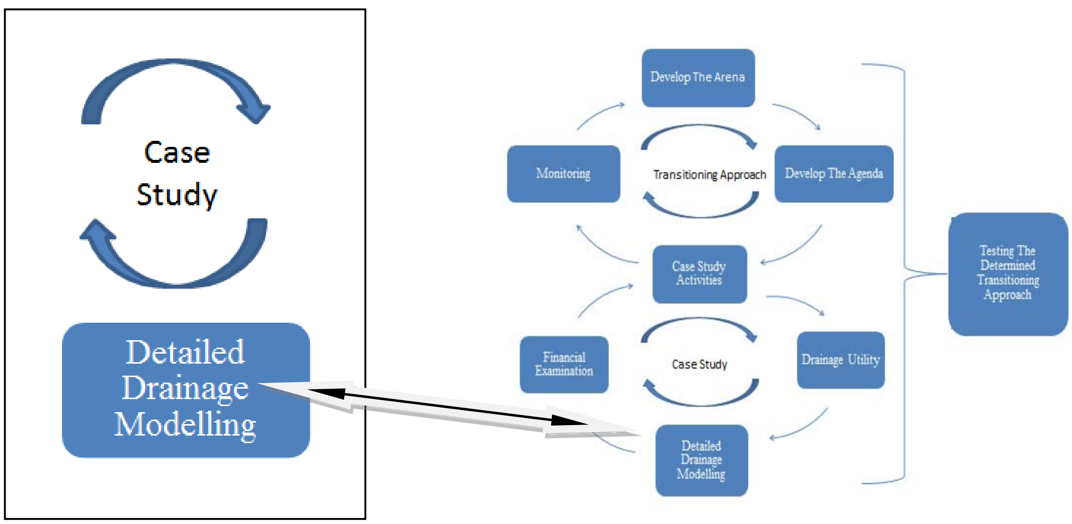

Figure 16 Case Study Stage Concerning Detailed Drainage Modelling

A wastewater system operated by Scotland's drainage utility was identified and utilised as a case study due to its key generic components (Fig 17) of 100% combined sewers, a wastewater pumping station (SPS), rising main, wastewater treatment works and model availability.

The modelling investigation will include running a number of differing scenarios of removing surface water from the combined sewer system from a number of different areas addressing baseline and total surface water flows under a variety of standard drainage modelling parameters.

The wastewater pumping station used as the basis of the investigations possesses two pumps operating on a duty/standby arrangement. The baseline flow is the term given to the flow from an area under current conditions and has the highest proportion of surface water inflows.

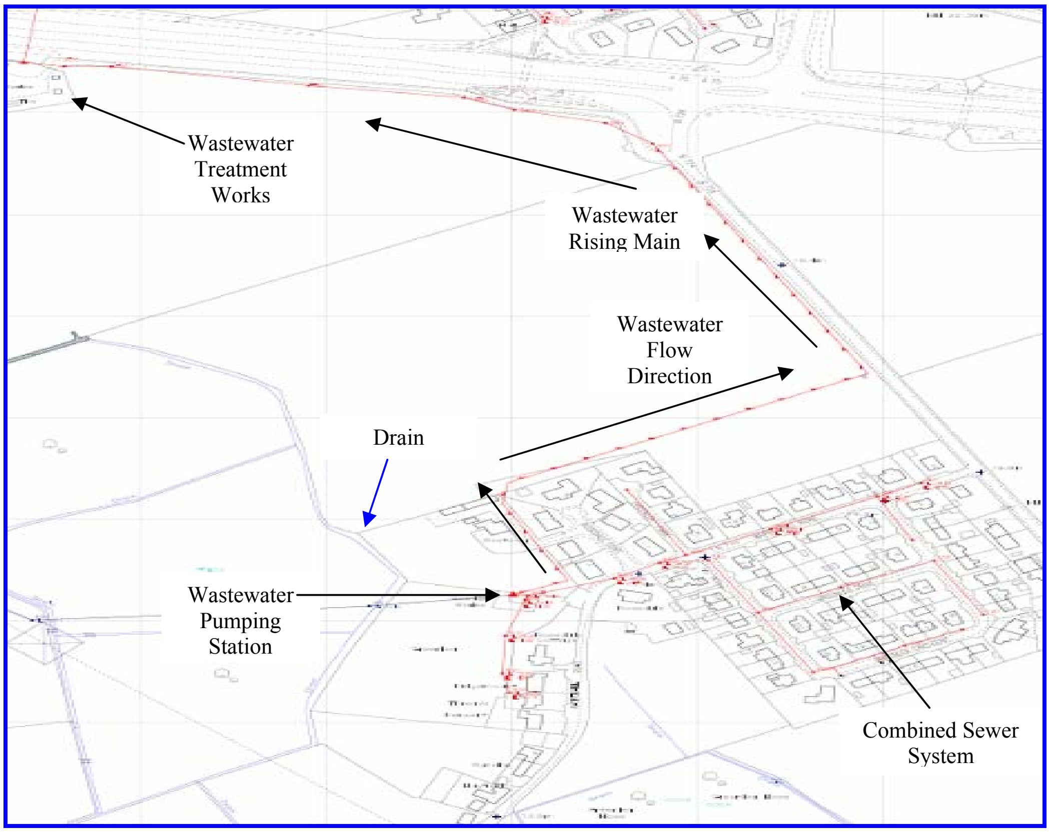

Figure 17 The Wastewater System

The modelling identified five distinct zones in the 90 property catchment possessing the potential for surface water removal thereby reducing the overall flows entering the SPS, the energy required and operational expenditure incurred. These zones (Fig 18) would provide information in determining and applying an appropriate retrofit SUDS project.

The sources of surface water were determined to be 57% originating from roads and 43% from roofs respectively.

It was decided, by the research author under advice from modelling professionals, to include both the surface water flows i.e., roofs and roads drainage as one flow due to the low volumes concerned. However the proportional split in other drainage catchments will vary depending upon the level of urbanisation.

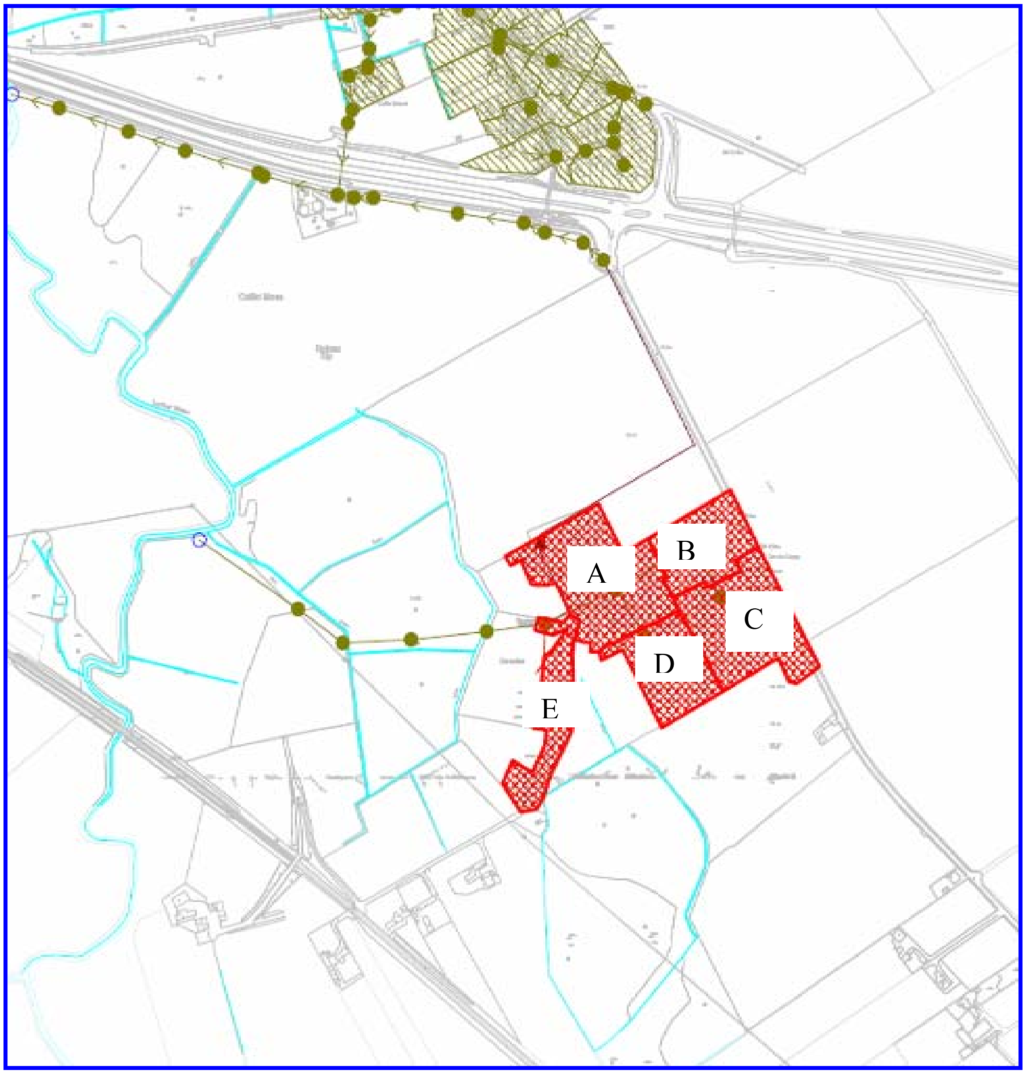

Figure 18 Wastewater System In The Case Study Catchment Separated Into Zones

Upon completion, the drainage modelling exercise was then expanded, utilising the same parameters, to investigate the volumes and duration of pumping station operation involved in a hypothetical scenario of a number of pumping stations operating in sequence under differing regimes, see Chapter 6.6.

6.2 DETAILED DRAINAGE MODELLING – Objective

The objective of the detailed drainage modelling exercise is to determine the pumping stations pass forward volumes and run time(s) for the identified catchments to obtain data to then conduct a detailed costing analysis.

6.3 DETAILED DRAINAGE MODELLING – Methodology

The volumes and durations of surface water removed from the designated zones (Fig 18) were investigated utilising the following parameters:

- Use the Case Study catchment as baseline scenario
- Calculate pass forward volumes at the PS (m^3)
- Calculate duration of the PS operation (min)
- Calculate spill volumes (if required)
- Presentation of results

and under the following industry accepted standard scenarios (Wallingford 2013)

Scenario 1. 1 in 1 Year Storm Event, of 60 minute duration

Scenario 2. 1 in 30 Year Storm Event, of 60 minute duration

Scenario 3. Typical Year, 168 Storm Events

The rainfall / design storms within the Infoworks software tool are produced by a rainfall generator tool (Chapter 2.7). All available rainfall data has been collated by the Meteorological office to derive statistical relationships. This tool allows the user to generate a representative rainfall event for any Scottish location from these relationships to create their own return periods and design storms for use in simulation runs. These storms can then be used to simulate the operational efficiency of the drainage network under varying conditions of return period and storm duration.

The three modelling scenarios (Chapter 3.7) were selected to provide the greatest level of information on storm events. Scenario 1 is the most basic storm event to be run using Infoworks modelling software and describes an event with 100% likelihood of occurring in Scotland, the 60 minute duration also the simplest time period. Scenario 2 possesses the storm event which represents rainfall most likely to result in severe surface water flooding in urban areas (Hurford et al 2012). Scenario 3 was selected to understand the detrimental impact a calendar years' worth of rainfall has on the operational efficiency of a wastewater network. The return periods and design storm durations scenarios selected are consistent with the drainage utilities specifications and guidelines for drainage area studies and skeletal models.

6.4 DETAILED DRAINAGE MODELLING – Results

6.4.1 Modelling Scenario 1.

Table 5 Surface Water Removal From Designated Zones In The Case Study Drainage Catchment (1 In 1 Year Event).

Operating Conditions	Volume Passed Forward (m^3)	Duration (h)
Baseline	**140**	**2.6**
Remove surface water from Zone A	135	2.5
Remove surface water from Zone B	108	2.0
Remove surface water from Zone C	117	2.17
Remove surface water from Zone D	99	1.83
Remove surface water from Zone E	126	2.33
Remove all Surface Water	**23**	**0.43**

6.4.2 Modelling Scenario 2.

Table 6 Surface Water Removal From Designated Zones In The Case Study Drainage Catchment (1 In 30 Year Event).

Operating Conditions	Volume Passed Forward (m^3)	Duration (h)
Baseline	**257**	**4.8**
Remove surface water from Zone A	256	4.7
Remove surface water from Zone B	211	3.9
Remove surface water from Zone C	216	4.0
Remove surface water from Zone D	198	3.7
Remove surface water from Zone E	243	4.5
Remove all Surface Water	**23**	**0.43**

6.4.3 Modelling Scenario 3.

Table 7 Annual Surface Water Removal From Designated Zones In The Case Study Drainage Catchment Over A Typical Year (168 Storm Events).

Operating Conditions	Total Volume Passed Forward(m^3)	Duration (h)
Baseline	**19,550**	**340**
Remove surface water from Zone A	18,350	317
Remove surface water from Zone B	15,000	256
Remove surface water from Zone C	17,350	299
Remove surface water from Zone D	15,800	271
Remove surface water from Zone E	17,650	305
Remove all Surface Water	**2,900**	**45**

6.5 DETAILED DRAINAGE MODELLING – Discussion

The modelling analysis addressed only the storm events since during normal operation in dry weather conditions no surface water should be present to require pumping.

6.5.1 Modelling Scenario 1.

Volumes - The Baseline Flow under these conditions (Table 5) at the pumping station is 140m³. Various runs of the model were conducted removing surface water resulting in a decrease from 140m³ for the Baseline to 23m³ with all surface water removed.

Duration - These volumes require the SPS to operate for 2.6hours to convey the storm flows as opposed to 0.43hours under dry weather operating conditions.

Reduction - This is a reduction of 117m³, 2.17hours which equates to 68%.

6.5.2 Modelling Scenario 2.

Volumes - The Baseline Flow under these conditions (Table 6) at the pumping station is 257m³. Various runs of the model were conducted removing surface water resulting in a decrease from 257m³ for the Baseline to 23m³ with all surface water removed.

Duration - These volumes require the SPS to operate from 4.7hours to convey the storm flows as opposed to 0.43hours under dry weather operating conditions.

Reduction - This is a reduction of 234m³, 4.57hours which equates to 91%.

6.5.3 Modelling Scenario 3.

Volumes – The Baseline Flow under these conditions (Table 7) at the pumping station was 19,550m³. Various runs of the model were conducted removing surface water resulting in a decrease of the volumes being pass forward by the pumping station from 19,500m³ to 2,900m³ with all the surface water removed. This is a reduction of 16,550m³ which is 85%.

Duration - These volumes required the SPS to operate continuously for the equivalent of 14days to convey the storm flows as opposed to under 2days equivalent in dry weather operating conditions.

Reduction - This is a reduction of 16,550m³, 12days which equates to 85%.

6.6 CONSECUTIVE PUMPING

6.6.1 Consecutive Pumping Introduction

A further scenario was conducted to examine the operation of the same pumping station as if it were operating in multiple conveying the flows prior to treatment under the typical year, 168 storm events scenario as depicted in the screenshot from the model (Fig 19).

The data obtained from the case study location was used to calculate the volumes and durations of comparable SPS's hypothetically receiving similar flows similar to the case study location so that there were 8 SPS's operating in sequence and terminating in discharge at the WwTW.

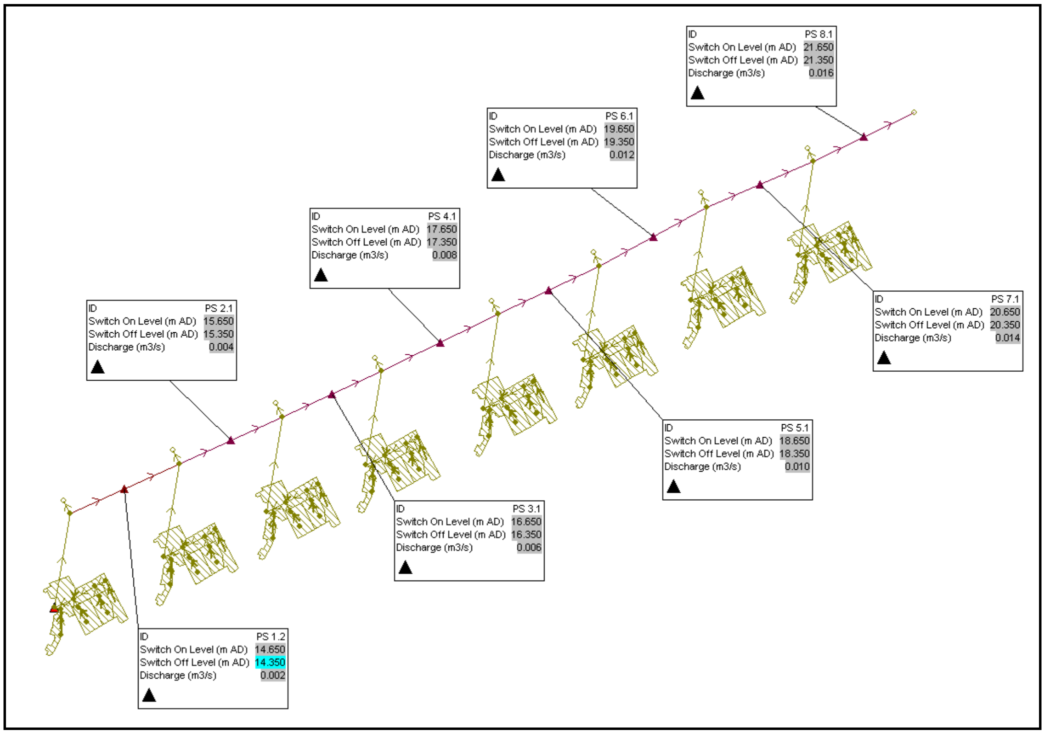

Figure 19 Representation Of The Theoretical Consecutive Pumping Modelling Scenario

6.6.2 Consecutive Pumping Objective

The objective of this investigation into the significance of consecutive pumping is to determine the pumping stations pass forward volumes and run time(s) for 8 No. linked theoretical catchments to obtain data to then conduct a detailed costing analysis.

6.6.3 Consecutive Pumping Methodology

The methodology used was as previous and included:

- Replicate the Case Study catchment and link 8No SPS's
- Calculate pass forward volumes at each PS
- Calculate duration of each PS operation (min)
- Calculate cumulative volumes and durations

To provide further information and supporting evidence to this objective the implications of alternative pumping regimes on the combined sewer system were conducted:

- Scenario 1. Multiples of DWF, increments of 3DWF. Starts at 2l/sec.
- Scenario 2. Original Data at SPS1 – increments of 15/sec.
- Scenario 3. Each SPS Pump Forward @15l/sec & Storage at 65m³.

6.6.4 Consecutive Pumping Results

Consecutive Pumping Station Operation - Volumes

Table 8 Volumes (m³) Requiring To Be Pumped For Consecutive Pumping Scenario

	Annual Totals											
	Multiples of DWF. Starts at 2l/sec. Increments of 3DWF				Original data at Warrenhill Rd SPS – increments of 15l/sec				Each SPS Pump Forward @ 15l/sec & Storage at 65m³			
	Combined		Separate		Combined		Separate		Combined		Separate	
Pumping Station	Freq	Volume m³	Freq	Volume m³	Freq	Volume m³	Freq	Volume m³	Freq	Volume m³	Freq	Volume m³
SPS1	168	13,072	168	4,136	168	23,721	168	3,634	168	23,050	168	4,067
SPS2	168	27,087	168	8,414	168	47,275	168	7,785	168	44,376	168	7,226
SPS3	168	41,993	168	12,756	168	70,414	168	19,569	168	57,745	168	10,903
SPS4	168	57,272	168	16,806	168	95,059	168	14,662	168	69,261	168	15,560
SPS5	168	72,955	168	20,573	168	118,154	168	16,922	168	79,945	168	19,327
SPS6	168	88,308	168	28,293	168	141,141	168	26,072	168	90,007	168	23,118
SPS7	168	103,344	168	30,436	168	163,084	168	21,786	168	99,641	168	27,473
SPS8	168	118,120	168	34,716	168	187,721	168	33,563	168	108,339	168	30,909

Consecutive Pumping Station Operation - Durations

Table 9 Durations Of Pumping Station Operation For Consecutive Pumping Scenario

Pumping Station	TSR Analysis											
	Multiples of DWF. Starts at 2l/sec. Increments of 3DWF				Original data at Warrenhill Rd SPS – increments of 15l/sec				Each SPS Pump Forward @ 15l/sec & Storage at 65m³			
	Combined		Separate		Combined		Separate		Combined		Separate	
	PF Duration (min)	O/F m³	PF Duration (min)	O/F m³	PF Duration (min)	O/F m³	PF Duration (min)	O/F m³	PF Duration (min)	O/F m³	PF Duration (min)	O/F m³
SPS1	108,465	10,247	34,679	0	19,587	0	2,618	0	24,276	0	3,700	0
SPS2	112,469	9,162	34,706	0	19,697	0	2,610	0	48,729	1,592	7,782	0
SPS3	116,071	8,230	34,539	0	19,750	0	2,606	0	63,709	9,501	11,984	0
SPS4	118,845	7,454	34,560	0	19,804	0	2,600	0	76,476	11,109	16,248	0
SPS5	121,145	6,794	34,411	0	19,847	0	2,598	0	88,330	11,629	20,608	0
SPS6	122,253	6,166	34,324	0	19,832	0	2,595	0	99,662	11,880	25,058	0
SPS7	122,648	5,678	34,281	0	19,852	0	2,594	0	110,408	12,122	29,430	0
SPS8	122,667	5,186	34,219	0	19,881	0	2,591	0	120,114	12,192	33,790	0

6.6.5 Consecutive Pumping Discussion

Numerous pumping operation scenarios were undertaken (Table 8 and 9) demonstrating the implications of multiple pumping of baseline flows and flows without surface water. The results of the overflow discharges have also been depicted to highlight that substantial flows are also discharged from the SPS's during storm events which result in significant detrimental impacts on the local environment and receiving watercourse.

- **Scenario 1. Multiples of DWF, increments of 3DWF. Starts at 2l/sec.**

Volumes - SPS1 is required to pass forward 13,0720m³ which increases to 118,120m³ at SPS8. When surface water is removed the volumes at SPS1 is 4,136m³ and increases to 34,716m³ at SPS8.

<u>Duration</u> – The baseline volumes require SPS1 to operate continuously for 75days (108,465mins) and for SPS8 to operate continuously for 85days (122,667mins). When surface water is removed SPS1 is required to operate for 24days (34,679mins) and SPS8 for 24days (34,219mins).

<u>Cumulative Impact</u> – An additional 83,359m³ of surface water requires SPS8 to operate for a further 51days. Also pertinent is the 58,917m³ which is spilled to the receiving watercourse and surrounding environment.

- **Scenario 2. Original Data at SPS1 – Increments of 15/sec.**

<u>Volumes</u> - SPS1 is required to pass forward 23,721m³ which increases to 187,721m³ at SPS8. When surface water is removed the volumes at SPS1 is 3,634m³ and increases to 33,563m³ at SPS8.

<u>Duration</u> – The baseline volumes require SPS1 to operate continuously 14days (19,587mins) and for SPS8 to operate continuously for 14days (19,881mins). When surface water is removed SPS1 is required to operate for 1.8days (2,618mins) and SPS8 for 1.8days (2,591mins).

<u>Cumulative Impact</u> – An additional 164,000m³ requires SPS8 to operate for a further 114days. Also pertinent is that there are zero flows, discharged through the overflow, to the receiving watercourse and surrounding environment.

- **Scenario 3. Each SPS Pump Forward @15l/sec & Storage at 65m³.**

<u>Volumes</u> - SPS1 is required to pass forward 23,050m³ which increases to 108,339m³ at SPS8. When surface water is removed the volumes at SPS1 is 4,067m³ and increases to 30,909m³ at SPS8.

Duration – The baseline volumes require SPS1 to operate continuously 17days (24,276mins) and for SPS8 to operate continuously for 84days (120,114mins). When surface water is removed SPS1 is required to operate for 2.5days (3,700mins) and SPS8 for 24days (33,790mins).

Cumulative Impact – An additional 85,289m³ arrives at SPS8 which requires the pumping station to operate for a further 67days. Also pertinent is the 12,192m³ which is spilled to the receiving watercourse and surrounding environment.

When the surface water is removed there is only a marginal volumetric increase which results in a much lesser increase in pumping station operational duration and no unnecessary and potentially detrimental spills.

6.7 SUMMARY

The case study drainage catchment was selected for investigation due to its key generic components of a typical wastewater combined sewer catchment; combined sewer network, sewage pumping station, rising main, wastewater treatment works and model availability.

Typically wastewater catchments across Scotland will contain at least one sewage pumping station due to the historical development of the village, town and city. Detailed drainage modelling results will vary across a range of catchments and be dependent upon the quality of baseline information gathered and applied at the project outset. The name, size, number of pumps and operational duration of the SPS under investigation will vary as will aspects like the length and diameter of the rising main however the principles will remain.

Prior to any detailed drainage modelling simulations being undertaken it is important to determine what the modelling outputs are going to be. This review period allows the user to develop and establish the modelling parameters for the outputs which they require such as identifying the sewers that surcharge or the predicted volumetric detriment at manholes during certain storm events. The data collected can then be utilised as the basis for construction activities or capital works.

This case study investigation concerned removing surface water flows prior to pumping to treatment in order to provide volumetric and pumping station operation duration information to greater understand the levels of energy consumed perhaps inefficiently by the drainage utility. The tasks carried out in this case study using detailed drainage modelling software (Innovyze 2015) can be replicated to achieve similar outputs for any other drainage catchment within Scotland.

Five distinct zones were identified to investigate the volumes of surface water removed from the existing combined sewer system and the potential for retrofitting SUDS. Volumes and durations of the case study pumping station's operation were investigated and obtained under three modelling scenarios, namely 1 in 1Year, 1 in 30Year and for 168storm events over the course of one full year.

In order to provide the greatest contrast between the findings, the information obtained under the two operating conditions, baseline and total removal of surface water flows were summarised.

Within the drainage utilities coverage, a number of drainage catchments operate multiple pumping stations in sequence. Further modelling scenarios were then undertaken, in the expanded experiment, to determine if there were a greater significance in the volumes and durations of pumping station operation as a result of operating in sequence.

Information on the pumping stations pass forward volumes and run time(s) for the identified catchments were obtained. The data collected allowed a detailed costing analysis to be undertaken (Chapter 7). The completion of these two tasks fulfilled the objective of the detailed drainage modelling exercises in Chapter 6.2 and 6.6.

The results obtained demonstrate that during storm events there are significant increases in both volume and spills from combined sewer overflows caused by surface water arriving at the final pumping station. The results also identify significant increases in duration initially calculated in minutes and ultimately reported in days.

The outputs of the detailed drainage modelling scenarios designed and performed can be seen as generic in nature in that they could be produced by utilising another drainage model for another catchment area.

As discussed in Chapter 1.1, alternative and innovative ways to deal with foul and surface water flows on the existing system should be investigated. The detailed drainage modelling information obtained from investigating the case study location recognises that during storm event conditions considerable surface water flows are being pumped to treatment.

Utilising a variety of detailed drainage modelling scenarios allowed that specific volumes requiring pumping and durations of pumping station operation to be determined to provide useable data for financial examination into the electricity costs incurred.

These principles were then adopted and applied in a hypothetical situation to greater understand the implications of consecutive pumping a practice widespread by the drainage utility under investigation.

With any analysis conducted using computer software packages there will be an inherent level of uncertainty in the results produced. The software should be viewed as a tool which can assist drainage industry practitioners in providing information to further guide the decision making process. This tool will however only be as accurate as the information used to construct it such as invert levels and cover levels, pipe diameters and pipe materials and gradients.

Model maintenance, calibration and verification exercises are performed on each model by the drainage utility to ensure any uncertainty in model performance is kept as low as practically possible. The accuracy of results of a verified model can vary depending upon the type of outputs determined at the outset (WaPUG, CoP, 2002).

- Peak Flow +25% to -15% at major peaks
- Flow Volume +20% to -10% excluding periods of poor data
- Peak Depth +0.5m to -0.1m under surcharge conditions with ± 0.1m at key locations under non-surcharge conditions.

When viewed across a large drainage catchment the margins of uncertainty in the results should be considered in the decision making process. At each stage of the modelling scenarios, there requires to be a sense check prior to proceeding to the next step to ensure that the analysis being conducted or the results being achieved are in line with what is expected.

In addition to the potential for errors to be contained within the computer software and the detailed drainage modelling scenarios conducted there is also the capacity for human error to have occurred (Graham 1999). The researcher may have misread information or collated data incorrectly. The potential for these errors to occur become exacerbated particularly during times of urgency through the application of speed and increasing pressure to complete tasks.

Confidence in the outputs from the modelling scenarios will also depend on the quality of the model used. The model utilised in this case study investigation has a high level of confidence rating. The asset data utilised to construct and verify the model will largely have originated from GIS data. Therefore the outputs will be intrinsically linked to the quality of data utilised in the initial construction phases. As part of the reporting procedure when constructing the model or during its verification phase the modeller produces and attaches a file report which informs any future user of the condition and level of performance of the model clarifying the limitations of the outputs.

In addition to the inherent level of uncertainty in results as described earlier there may be limitations linked to particular features within the model. Pump pass forward rates may have been assumed. The rates utilised in the modelling scenarios are therefore theoretical and potentially unrealistic rather than based on actual source data thereby possessing a higher degree of certainty.

Whichever detailed drainage model or rainfall / design storm event is selected it is important to determine and agree this is the correct parameters to be utilised so that an agreeable analysis can then be undertaken.

The volumes and durations obtained through detailed drainage modelling completes objective 3 of research aim 2, and provides further information and justification to adopt and implement a suitable transitioning approach to achieve a more efficient and effective utilisation of wastewater assets and infrastructure.

CHAPTER 7 CASE STUDY: FINANCIAL EXAMINATION

7.1 INTRODUCTION

This chapter describes the third of the key activities of the case study stage of the developed transitioning approach completing research aim 3 by examining the financial implications of removing and attenuating surface water flows from the combined sewer system (Fig 20).

This examination will identify the grid electricity costs and any potential electricity savings under the varying scenarios undertaken, the estimated costs to retrofit SUDS, the significance of consecutive pumping and the impacts at the local and national level highlighting the effect of the recent introduction of the “Rain Tax” on UK Householder’s (Customers) (Bennett 2011).

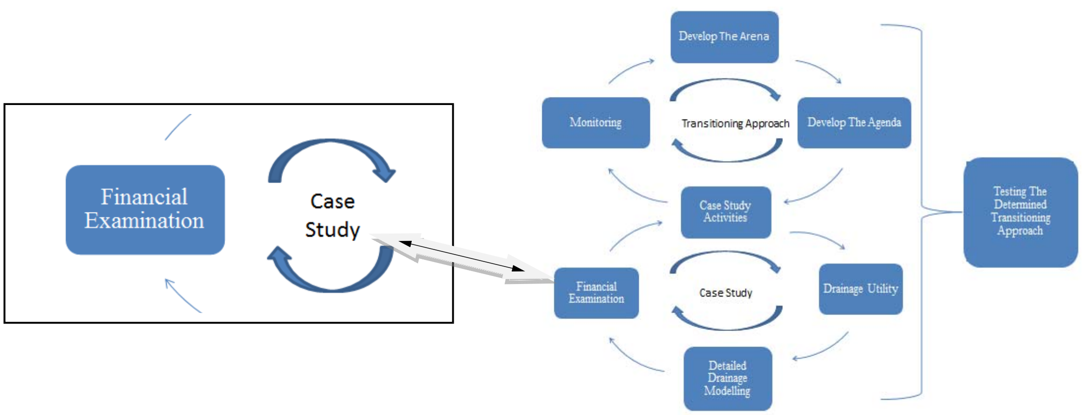

Figure 20 Case Study Stage Concerning Financial Examination

7.2 DETAILED DRAINAGE MODELLING COSTS

The modelling conducted in Chapter 6, produced information and data to allow potential quantifiable costs to be investigated. The next step examined and calculated the financial implications of removing/attenuating surface water flows from the combined sewer system prior to pumping under varying scenarios and up to 2035, achieving objective 4 of research aim 3.

7.2.1 Detailed Drainage Modelling Costs - Objective

The objective of the financial investigation is to determine the energy consumption costs incurred at pumping stations to pass forward volumes for the identified catchments in order to measure the financial significance of unnecessarily transporting surface flow prior to treatment.

7.2.2 Detailed Drainage Modelling Costs - Methodology

The price for electricity in 2010 incurred by the drainage utility to operate the pumping station investigated is £0.78KWH. The volumes and durations of the pump operation are known. By applying a calculation for duration against the electricity price, a cost per event and per scenario can be determined. The current profile is 2010 and the future view is 2035, 25 years hence.

7.2.3 Detailed Drainage Modelling Costs - Results

- **Scenario 1. 1 in 1 Year Storm Event, of 60 minute duration**

The volumes and durations of surface water removed from the designated zones in Figure 18 for a 1 in 1Year Storm Event of 60minute duration were modelled and the results with the costs of power applicable are given in Table 10.

Table 10 Surface Water Removal From Designated Zones In The Case Study Drainage Catchment (1 in 1 Year Storm Event, of 60 minute duration).

Operating Conditions	Volume Passed Forward (m^3)	Duration (h)	Power cost (£)
Baseline	**140**	**2.6**	**2.03**
Remove Zone A	135	2.5	1.95
Remove Zone B	108	2.0	1.56
Remove Zone C	117	2.17	1.69
Remove Zone D	99	1.83	1.43
Remove Zone E	126	2.33	1.82
Remove all Surface Water	**23**	**0.43**	**0.34**

- **Scenario 2. 1 in 30 Year Storm Event, of 60 minute duration**

The volumes and durations of surface water removed from the designated zones in Figure 18 for a 1 in 30Year Storm Event of 60minute duration were modelled and the results with the costs of power applicable are given in Table 11.

Table 11 Surface Water Removal From Designated Zones In The Case Study Drainage Catchment (1 In 30 Year Event).

Operating Conditions	Volume Passed Forward (m^3)	Duration (h)	Power cost (£)
Baseline	**257**	**4.8**	**3.75**
Remove Zone A	256	4.7	3.67
Remove Zone B	211	3.9	3.04
Remove Zone C	216	4.0	3.12
Remove Zone D	198	3.7	2.89
Remove Zone E	243	4.5	3.51
Remove all Surface Water	**23**	**0.43**	**0.34**

- **Scenario 3. Typical Year, 168 Storm Events**

The volumes and durations of surface water removed from the designated zones in Figure 18 over a typical year (a dataset with 168 storm events) were modelled and the results with the costs of power applicable are given in Table 12.

Table 12 Annual Surface Water Removal From Designated Zones In The Case Study Drainage Catchment Over A Typical Year (168 Storm Events).

Operating Conditions	Total Volume Passed Forward (m^3)	Duration (h)	Power cost (£)
Baseline	**19,550**	**340**	**265**
Remove Zone A	18,350	317	247
Remove Zone B	15,000	256	200
Remove Zone C	17,350	299	233
Remove Zone D	15,800	271	211
Remove Zone E	17,650	305	237
Remove all Surface Water	**2,900**	**45**	**35**

- **Scenario 4. Cost for 2010 - 2035**

The volumes and durations of surface water removed from the designated zones in Figure 18 were calculated and the results with the costs of power applicable for 2010 and using a 3.5% discount rate (Chapter 3.7.1) cumulatively for 2035 are given in Table 13.

Table 13 Annual Power Costs For Designated Zones In The Case Study Drainage Catchment.

Operating Conditions	Annual Power Cost (£) Today	Cumulative Present value of Costs (£) to 2035
Baseline	**265**	**4,368**
Remove Zone A	247	**4,071**
Remove Zone B	199	**3,280**
Remove Zone C	233	**3,840**
Remove Zone D	211	**3,477**
Remove Zone E	237	**3,906**
Remove all Surface Water	**35**	**577**

7.2.4 Detailed Drainage Modelling Costs - Discussion

From the results of the initial modelling experiment conducted and obtained in Chapter 6, it is evident that there is a volumetric and durational benefit which could be achieved by not passing forward surface water flows. These figures allow the electricity consumption costs to be determined and the potential savings achievable to be calculated and understood.

- **Scenario 1. 1 in 1 Year Storm Event, of 60 minute duration**

The cost of power to transport the Baseline flow (Table 10) during this storm event was £2.03. This reduced to £0.34 when all surface water was removed, a potential annual saving of £1.69 (83% reduction).

- **Scenario 2. 1 in 30 Year Storm Event, of 60 minute duration**

The cost of power to transport the Baseline flow (Table 11) during this storm event was £3.75. This reduced to £0.34 when all surface water was removed, a potential saving of £3.41 (91%).

- **Scenario 3. Typical Year, 168 Storm Events**

The assessment using 168 storm events for a typical year identified a significant difference between the pumped flows with and without surface water, causing an avoidable financial expenditure. To pump baseline flows over these 168 events (Table 12) incurred an annual power cost of £265 as opposed to a power cost of pumping the dry weather flow at £35, a potential saving of £230 (87%).

- **Scenario 4. Cost Profile 2010 - 2035**

The current profile is 2010 and the future view is 2035, 25 years hence. The annual power costs for 2010 and a predicted annual power cost with a 3.5% discount rate (Chapter 3.7.1) showing the net present worth of financial expenditure up to 2035 for each scenario can be seen in Table 13.

The energy cost of pumping the baseline flow calculated over the 25 year period (2010 - 2035) is £4,368 (Table 13) as opposed to pumping the dry weather flow alone over the same period at £577, a potential saving of £3,791 (87%).

It is clear that there is a considerable difference between the energy cost for pumping the baseline flow and the dry weather flow however, the absolute values of flow and money involved are low.

Every drainage utility is faced with a number of pressures to modernise its numerous above and below ground assets and infrastructure, so as to reduce leakage and improve treatment, whilst continuing to provide secure and safe water and wastewater services through upgrading unsatisfactorily performing pipes.

During the 2012/13 investment programme, the drainage utility in Scotland delivered £487 million of improvements (Scottish Water 2013). On the basis that a wastewater system contained only one pumping station which was operating adequately in that it was conveying flows without any unsatisfactory intermittent discharges, the system would be unlikely to feature in the improvements programme and therefore no action would be taken unless other drivers applied, and thus no transition would occur.

7.2.5 Detailed Drainage Modelling - Consecutive Pumping Costs

Utilising the information obtained from the initial modelling investigation at the case study location a financial investigation was undertaken to combined the findings of the annual consumption over the 25year period with a theoretical 8SPS's operating in sequence (Fig 19).

The previous assessment (Tables 10, 11, 12 and 13) identified three main areas:

- Scenario 1. Annual Baseline Costs 2010 and Cumulative Costs 2035
- Scenario 2. Removal of Surface Water Costs 2010 and Cumulative Costs 2035
- Scenario 3. Annual Savings 2010 and 2035

Table 14 Annual Power Cost Implications With Sequential Pumping Over 25years

SPS	Baseline 2010 Annual Costs £	Baseline 2035 Cumulative Costs £	Removal of Surface Water 2010 Annual Costs £	Removal of Surface Water 2035 Cumulative Costs £	2010 Annual Savings £	2010 – 2035 Cumulative Savings £
1	265	**4,368**	35	**577**	230	**3,790**
2	530	**8,734**	70	**1,154**	460	**7,581**
3	795	**13,102**	105	**1,730**	690	**11,371**
4	1,060	**17,469**	140	**2,307**	920	**15,162**
5	1,325	**21,836**	175	**2,884**	1,150	**18,952**
6	1,590	**26,203**	210	**3,461**	1,380	**22,742**
7	1,855	**30,570**	245	**4,038**	1,610	**26,533**
8	2,120	**34,938**	280	**4,614**	1,840	**30,323**
Total	**9,540**	**157,219**	**1,260**	**20,765**	**8,280**	**136,454**

Scenario 1. Annual Baseline Costs 2010 and Cumulative Costs 2035

The cost of power to transport the Annual Baseline flow at SPS1 was £265 in 2010 which increased to £4,368 in 2035 (Table 14), whilst the cost of power at SPS8 to transport the Annual Baseline flow was £9540 in 2010 which increased to £157,219 in 2035.

Scenario 2. Removal of Surface Water Costs 2010 and Cumulative Costs 2035

The cost of power to transport the flows with the surface water component removed at SPS1 in 2010 was £35 which increased to £577 in 2035 (Table 14), whilst the cost of power at SPS8 to transport the flow with the surface water component removed was £1,260 in 2010 which increased to £20,765 in 2035.

Scenario 3. Annual Savings 2010 and 2035

The cost of power to transport the flows without the surface water component removed achieves a saving of £230 in 2010 (87%), which increases to £3,790 in 2035 (Table 14). The cost of power at SPS8 to transport the flow with the surface water component removed in 2010 achieves a savings of £8,280 (87%) which increases to £136,454 in 2035.

This is a noteworthy saving for one wastewater system particularly when extrapolated nationwide. These findings identify the reductions which can be achieved when assessing SPS's at the national level, however there will be costs incurred to disconnect the surface water flows.

7.3 SUDS RETROFIT COSTS

A variety of SUDS can be retrofitted to remove and or reduce the surface water flows entering the combined sewer system (Chapter 2.6.3). Whilst the volumes of surface water removed and the energy consumption required during storm events have been identified, the financial implications of retrofitting SUDS in the catchment requires investigation and determination. The examination of the costs incurred achieves objective 5 and research aim 3.

7.3.1 SUDS Retrofit Costs - Objective

The objective is to determine the estimated costs incurred to retrofit SUDS across the catchment thereby advancing the understanding of the financial significance of unnecessarily transporting surface water to treatment.

7.3.2 SUDS Retrofit Costs - Methodology

The retrofit methodology followed a desktop approach involving the identification of a variety of potential SUDS suitable for retrofitting such as swales, basins, raingardens (Chapter 2.4.5). The detailed drainage model discussed in Chapter 6 was utilised to provide information relating to the length of roads and impermeable areas. The data obtained allowed the volume of storage required and the sizes of the Swale and Basin solutions to be calculated.

The following specific SUDS were selected for financial examination using whole life costing tools namely WERF BMP and LID cost models and SUDS For Roads.

- Roof Drainage Disconnection – Raingardens
- Road Drainage Disconnection – Swale, Basin

The retrofit methodology was expanded to involve the identification of a variety of potential non-SUDS suitable for retrofitting such as water butts, separate surface water sewers and permeable paving.

The following specific non-SUDS were selected for financial examination using the cost of currently available industry wide products, whole life costing tools namely WERF BMP and LID cost models and SUDS For Roads, and the construction cost handbook CESMM3 (2011) Carbon and Price Book 2011.

- Roof Drainage Disconnection – Water Butts
- Road Drainage Disconnection – Pipework and Permeable Paving

The combination of retrofitting SUDS and non-SUDS were selected in order to provide the total cost benefit of retrofitting solution, the potential volume of greenhouse gas emissions (CO2e) saved per year and additional information to support the financial significance of removing and or reducing surface water flows in combined sewer systems.

Details of the specific financial calculations are contained within Appendix 3 SUDS Retrofit Financial Examination

7.3.3 SUDS Retrofit Costs – Results and Discussion

<u>Retrofit SUDS - Roof Drainage Disconnection - Raingardens</u>

The drainage area catchment consists of 90 residences, all with the potential to disconnect the roof drainage from the combined sewer system (Chapter 2.4.4). Raingardens can be utilised by the homeowner to collect and /or direct the disconnected surface water flows originating from the roof and driveway into the raingarden structure (Wadsworth et al 2014), thereby providing multiple benefits including further amenity to the garden area. The estimated cost, utilising the WERF BMP and LID Cost Tool for retrofitting 90 raingardens across the catchment (Chapter 2.4.5) are itemised in Table 15. The option of utilising soakaways as a potential solution was discounted due to lack of information on soil properties at the case study location.

Table 15 Roof Drainage Disconnection – Raingarden

Area	Description	Construction Cost	Maintenance (30Yrs) Cost	Whole Life (30Yrs) Cost
Roof Drainage Disconnection	1 Raingarden	£2,614	£21,155	£23,852
	90 Raingardens	£235,260	£2,146,680	£2,381,940

Retrofit Non - SUDS Roof Drainage Disconnection - Water Butts

There are a variety of non-SUDS devices with which to collect the surface water one of which is a Water Butt (Chapter 2.5.1). These are currently available (June 2015) from the drainage utilities partner, www.savewater.co.uk with an estimated cost as itemised in Table 16.

Table 16 Roof Drainage Disconnection – Water Butt

Area	Description	Size	Cost per unit	Number of units	Total Cost
Roof Drainage Disconnection	Water Butt	100 litres	£37.95	90	£3,415.50
		190 litres	£49.95	90	£4,495.50

Retrofit SUDS - Road Drainage Disconnection - Swale and Basin

The catchment possessing 1.43Km of public roadway has the potential to disconnect all of the road drainage prior to entering the combined sewer system. There are a variety of SUDS retrofit solutions which can be retrofitted to collect, transport, attenuate and provide a level of treatment. The estimated costs, utilising the whole life costing tool SUDS For Roads, for retrofitting a Swale and a Basin are itemised in Table 17.

Table 17 Road Drainage Disconnection – Swale and Basin

Area	Description	Construction Cost	Maintenance (30yr) Cost	Whole Life (30Yrs) Cost
Road Drainage Disconnection	Swale	£6,775	£19,392	£26,167
	Basin	£11,367	£18,558	£29,925

Retrofit Non - SUDS Road Drainage Disconnection - Pipework

The estimated cost, utilising the construction cost handbook CESMM3 (2011) Carbon and Price Book 2011, for retrofitting a surface water sewer network across the catchment, approx. 1.43Km in length (Chapter 2.4.3) are itemised in Table 18.

Table 18 Road Drainage Disconnection – Pipework

Area	Description	Construction Cost
Road Drainage Disconnection	Pipework	£130,682

Maintenance and whole life costing's were unable to be generated utilising the CESMM3 Carbon and Price Book 2011 approach.

Retrofit Non - SUDS Road Drainage Disconnection - Permeable Paving

The estimated cost, utilising the whole life costing tool WERF BMP and LID Cost Tool, for retrofitting the permeable paving as the road and path surface across the catchment (Chapter 2.4.5) are itemised in Table 19. The length of road = 1.43Km. The width of the road + footpath = 6metres. Total permeable area = 1.43Km x 6m = 8.58Km².

Table 19 Road Drainage Disconnection – Permeable Paving

Area	Description	Construction Cost	Annual Maintenance Cost	Whole Life (25Yrs) Cost
Road Drainage Disconnection	Permeable Paving	£220,525	£3,776	£221, 598

Costs calculated utilising the WERF BMP and LID Cost tool were initially quoted in US Dollars. These costs were converted using the US Dollars to UK Sterling currency exchange rate 1Dollar = 0.65Pounds (23rd May 2015) (Appendix 3).

The figures obtained for each component were then utilised in the decision support tool from UKWIR 09/WM/07/13, (Conlan et al 2009) to determine the total cost benefit of the retrofit solutions. To retrofit the solutions identified would result in a total cost benefit of - £101,298 and -12tonnes CO2e per year (Negative value for CO2e is a saving) (see Appendix 3 UKWIR WM07 DST).

For all solutions investigated the cost relating to detailed design, Construction Design Management (CDM), site set up, welfare have not been included. Further omissions relate to costs incurred for land purchase, negotiations with land agents and solicitors. In addition it should be noted that the costs stated would be subject to fluctuations in the competitive market place and may yield an improved or increased cost.

7.3.4 SUDS Retrofit Costs – Summary

A variety of SUDS and non-SUDS can be retrofitted to remove and or reduce the surface water flows entering the combined sewer system.

This section conducted a financial examination into the implications of retrofitting SUDS and non-SUDS across the catchment (Table 20) by utilising a desktop approach involving whole life cost tools and a construction cost handbook (Chapter 2.6.3).

Table 20 Costs Per Drainage Disconnection Item

Area	Description	Construction/Capital Cost	Maintenance (30Yrs) Cost	Whole Life (30Yrs) Cost
Roof Drainage Disconnection	1 Raingarden	£2,614	£21,155	£23,852
	90 Raingardens	£235,260	£2,146,680	£2,381,940
	Water Butt 90 @ 100litres	1@£37.95 = £3,415.50	--	--
	Water Butt 90 @ 190litres	1@£49.95 = £4,495.50	--	--
Road Drainage Disconnection	Pipework	£130,682	--	--
	Swale	£6,775	£19,392	£26,167
	Basin	£11,367	£18,558	£29,925
	Permeable Paving	£220,525	£3,776	£221,598

A decision support tool was then utilised to calculate the total cost benefit of minus £101,298 with a saving of 12tonnes of greenhouse gas emissions (CO2e) per year from retrofitting the solutions (Chapter 2.3) (Appendix 3).

This examination of the costs incurred achieves objective 5 and research aim3 advancing the understanding of the financial significance of unnecessarily transporting surface water to treatment.

7.4 LOCAL LEVEL COSTS

The research used as its basis a singular wastewater pumping station which can be seen as research at the local level. The pumping station under investigation operated on a combined sewer flow pumping regime of 15l/sec which was activated only occasionally over 24hrs and as and when required.

The drainage utility however possesses significantly larger SPS with some operating dual combined and storm pumps. The improvement drivers identified and achievable at the local level could be extrapolated up to apply to larger SPS'S which the drainage utility operates.

Currently at a number of locations across Scotland, surface water is pumped several times in order to receive treatment at the Wastewater Treatment Works. This leads to a considerable and unnecessary financial burden on the drainage utility because of the costs of pumping.

The McDonald Road SPS (Fig 21) one of the drainage utilities larger SPS's, possesses two screw pumps one for dry weather and the other for storm water is at the end of a series of consecutive SPS's. The pumping regime at McDonald Road SPS, which is in continuous operation, is 1800l/sec with the provision to start up the storm pumps thereby conveying up to an additional 2700l/sec during storm events.

The effect of increased urbanisation is such that both pumps are in continuous operation with the overflow at the penultimate SPS at Albert Road in even greater use.

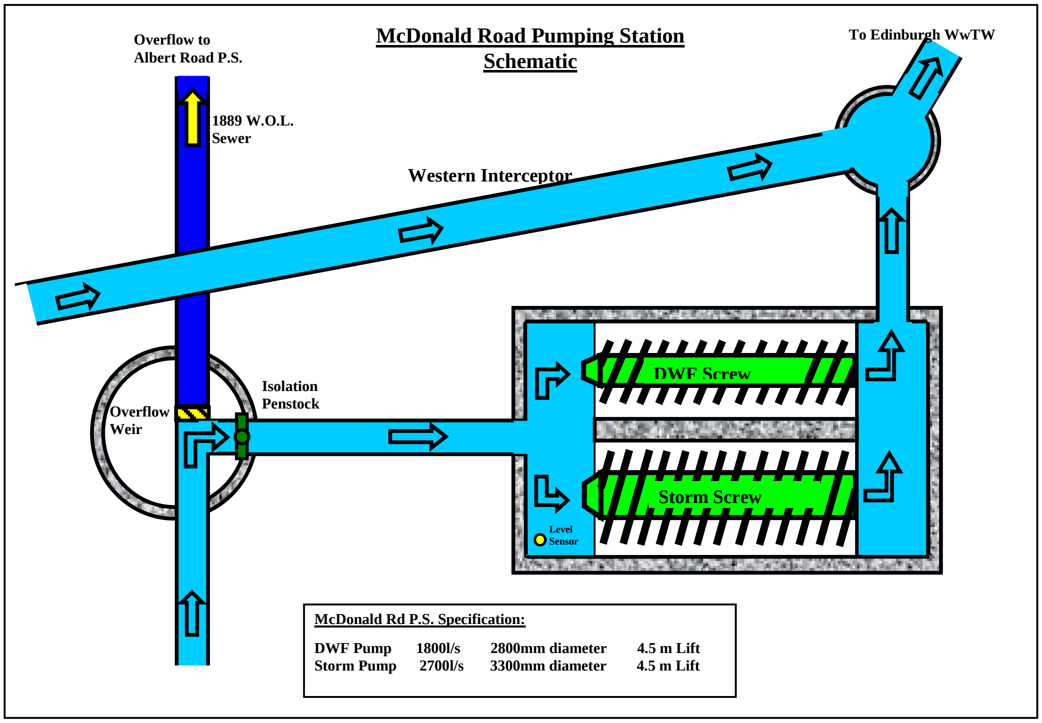

Figure 21 MacDonald Road Pumping Station, Edinburgh (Research Author 2013)

The principles of the research investigated at the case study location can be directly applied for example to the McDonald Road SPS and the energy consumption required to unnecessarily convey surface water flows prior to treatment is worth further investigation due to the volumes concerned.

Similarly the financial implication of consecutively pumping surface water from one pumping station to the next, prior to receiving treatment, in this theoretical example over 25 years is considerably less than the financial expenditure required to implement a variety of retrofit sustainable urban drainage solutions.

However a common theme from all of these findings has emerged, that a considerable volume of unnecessary flows are being transported by pumping stations which require the pumps to operate for longer durations thus incurring increasing electricity costs.

In reality, pumping stations will pass forward even higher flows due to increased catchment areas, some ultimately operating 24hrs and 365days such as McDonald Road SPS, possessing numerous pumps of an increased size and the complexity and the financial expenditure required becomes ever substantial.

7.5 NATIONAL LEVEL COSTS

At the national level, the drainage utilities annual bill for power in 2011 see Chapter 2.3, was £40 million of which 71.8% of greenhouse gas emissions and £28,720,000 is for grid electricity used for the conveying of flows utilising 2,100SPS's throughout the wastewater system and 1,800 WwTW for treatment (Scottish Water 2011). The drainage utility recognises that considerable savings can be obtained from improving energy efficiencies with the wastewater processes (Scottish Water 2015b).

7.5.1 National level Costs - Objective

The objective of the financial investigation is to determine the electricity consumption costs incurred at pumping stations to pass forward volumes at the national level achieving objective 6 and research aim 3 in order to greater understand the financial significance of unnecessarily transporting surface flow prior to treatment during storm conditions.

7.5.2 National Level Costs - Results

The drainage utility transports and treats 864 megalitres per day and 315,360 megalitres per year (Scottish Water 2011). Grid electricity accounts for 71.8% of the drainage utilities greenhouse gas emissions costing £28,720,000.

Grid electricity consumption by greenhouse gas emissions comprises 18.9% for the wastewater network and 41.8% wastewater treatment processes accounting for 40% of the total volume of greenhouse gas emissions.

Wastewater Network 18.9% of £28,720,000 equates to £5,428,080.

Wastewater Treatment 41.8% of £28,720,000 equates to £12,004,960

7.5.3 National Level Costs - Discussion

The research at the case study location identified an 87% financial saving in the annual grid electricity consumed at the pumping station by removing the surface water flows from the combined sewer system prior to pumping.

Indeed the financial implications of transporting surface water to treatment often consecutively as identified in this research emphasise and magnify the savings achievable by the drainage utility. However retrofit solutions have yet to be implemented at the national level and there is a lack of justifiable evidence as put forward by Casal-Campos et al (2015) to the magnitude and scale of the benefits achievable.

Wastewater System

The drainage utility currently operates over 2,100 wastewater pumping stations on the wastewater system, all of which transport combined sewer flows, with others being in a state of abandonment, refurbishment, construction and adoption. In addition there are a further 400 wastewater pumping stations which are either owned or privately operated such as through the Public Finance Initiative, PFI (Scottish Water 2013).

The expenditure incurred through grid electricity consumption for a wastewater system comprising 2,100SPS's applying the principles obtained from the case study research has the potential to be considerably reduced from 18.9% of the drainage utilities annual bill at £5,428,080, and may be quantified in millions of pounds of savings as opposed to pounds and pence per annum.

Wastewater Treatment

The annual bill for wastewater treatment at 41.8% accounts for a sizeable proportion of the drainage utilities total annual expenditure on grid electricity. Removing the surface water flows prior to pumping will reduce the 315,360megalitres being received at the wastewater treatment works requiring treatment incurring £12,004,960 in grid electricity expenditure.

7.6 HOUSEHOLDS (CUSTOMERS) AND THE "RAIN TAX"

In addition to the drainage utility achieving savings through electricity consumption, savings can also be achieved by householders from their annual bills by disconnecting their surface water flows prior to entering the combined sewer system achieving objective 6 and research aim 3.

In the UK, the surface water drainage charge currently levied by drainage utilities on customers has been dubbed the "Rain Tax" (Bennett 2011). Many UK drainage utilities now offer incentive schemes to their customers to disconnect their surface water flows.

The principal focus is to reduce the volumes of surface water the drainage utility has to process by generating a greater implementation of SUDS technologies, however the uptake is typically low at around 2 - 4% of households (Bennett 2011). One of the main reasons for the low uptake is that there is a lack of transparency in the charging system.

In Scotland, the local Council presents and collects the drainage utility's charges. These charges are explained under two headings namely; the Water charge and the Wastewater charge (City of Edinburgh Council 2013).

The data collected focuses upon the charges for the wastewater services provided by the drainage utility for the financial year April 2013 - March 2014 for Households.

Charges for wastewater services, 2013 - 2014 (Table 21) are categorized under two situations whether or not the household does or does not have a water meter.

1. The property does not have a Water meter

If the Property does not have a Water meter, the most common situation, then unmetered charges are based on the Council Tax band of the house (City of Edinburgh Council 2013). The unmetered household charges based on The City of Edinburgh's Council literature are as follows:

Table 21 Household Charges Per Council Tax Band, (2013-2014) (City of Edinburgh Council 2013)

Council Tax Charge	Band A	Band B	Band C	Band D	Band E	Band F	Band G	Band H
Water	£124.80	£145.60	£166.40	£187.20	£228.80	£270.40	£312.00	£374.40
Wastewater	£144.84	£168.98	£193.12	£217.26	£265.54	£313.82	£362.10	£434.52
Combined	£269.64	£314.58	£359.52	£404.46	£494.34	£584.22	£674.10	£808.92

<u>Wastewater – Foul Drainage, Property Drainage and Roads Drainage Charges</u>

Wastewater Charges as stated by Scottish Water in July 2013: "Waste water charges – you pay these if your property is connected to the public sewer either to drain waste water from inside your property or to drain rainwater from your property. Waste water charges also apply at properties that benefit from facilities which drain to a public sewer or drain, or where an overflow from a septic tank is connected to a public sewer or drain".

Through examining the drainage authorities Scheme of Charges 2013/2014 (Scottish Water 2013) it is possible with some investigation to obtain further information and determine the proportional cost per component of the Wastewater charge which would assist the householders make an informed decision in regards their participation in a potential disconnection programme and future retrofit schemes. The figures as shown in Table 22, are not currently displayed together within the literature presented with The City of Edinburgh Council Tax bill.

Table 22 Breakdown Of Wastewater Services By Component for 2013 – 2014 (City of Edinburgh Council 2013)

Council Tax Charge	Band A	Band B	Band C	Band D	Band E	Band F	Band G	Band H
Foul	£86.90	£101.39	£115.87	£130.36	£159.32	£191.29	£217.26	£278.71
Roads	£28.97	£33.80	£38.62	£43.45	£53.11	£63.76	£72.42	£92.90
Property	£28.97	£33.80	£38.62	£43.45	£53.11	£63.76	£72.42	£92.90
Total	£144.84	£168.99	£193.11	£217.26	£265.54	£318.81	£362.10	£464.51

Additional clear representations of the wastewater services charge which could be included in the City of Edinburgh Council tax bill are shown in Figure 21 and Figure 22.

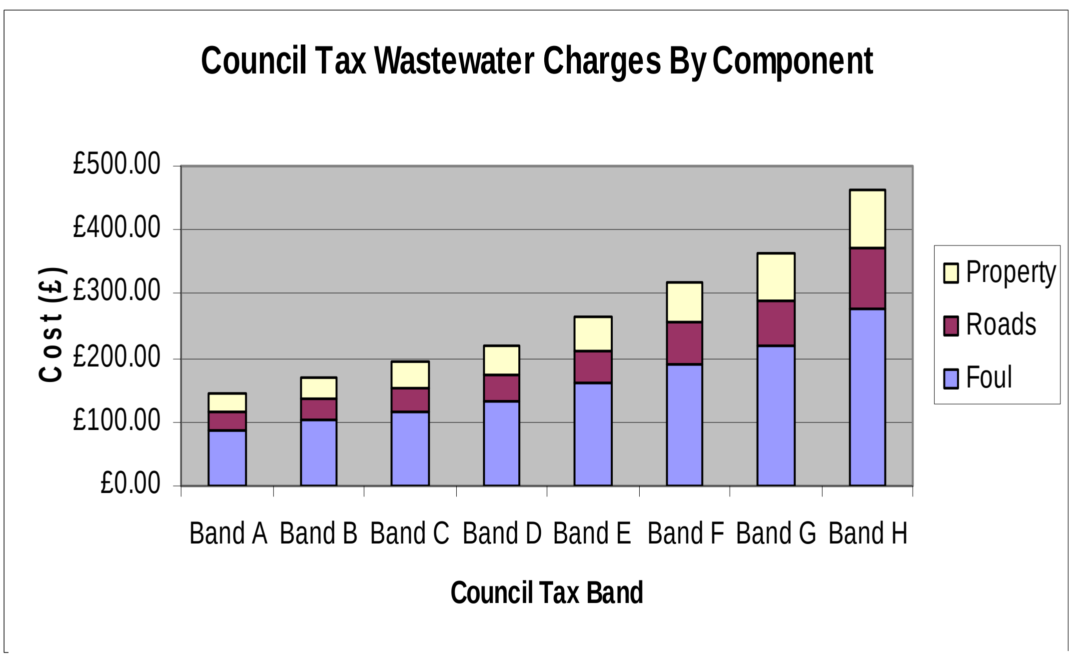

Figure 22 Components Of The City Of Edinburgh Council's Tax Waste Charges 2013-2014, (City of Edinburgh Council 2013)

Where they have a drainage connection to the infrastructure all domestic customers must also pay for the surface water from the roads. Where the drainage utility deals with no property drainage from any part of the property no property drainage charge will be applied.

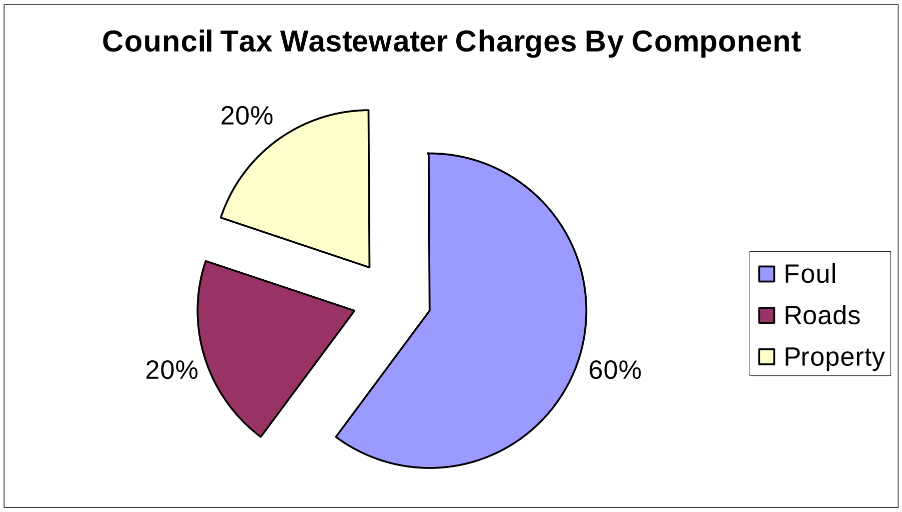

Figure 23 Proportional Representation Of The City Of Edinburgh Council Tax Wastewater Charges 2013-2014.

With the property having the roof drainage disconnected the domestic customer could potentially save 50% of the Surface Water charge.

- 60% Foul
- 40% Surface Water = 50% Roof Drainage and 50% Roads Drainage

For example a property at Band E, the Wastewater charge total is £265.54, this is made up of 60% Foul, 20% Roads and 20% Property Drainage (Fig 23). With the property having the roof drainage disconnected the domestic customer could potentially save £53.11 (10.7%) annually from their Wastewater bill.

- £159.32 would be for Foul draining from the property
- £53.11 would be for SW draining from the property
- £53.11 would be for SW draining from the roads

In direct similarity to the results obtained through investigating the hypothetical drainage system and modelling the reduction in energy consumption, the figures applicable are minor at the individual and local level, however when extrapolated up the financial implications quantifiable are considerable.

There is advice in The City of Edinburgh Council Tax literature (City of Edinburgh Council 2013) on discounts from the Council Tax bill such as if the occupancy is single person, the property is vacant or is a second home etc., yet no information is provided on discounts on the Water and Wastewater services.

Clearer advice comes from a scheme offered by Yorkshire Water (Yorkshire Water 2013), which advises their customers that by disconnecting their properties surface water drainage, and by demonstrating the flows discharge elsewhere the customer can receive an annual rebate off their wastewater services charge of £45.96 or at least 10%.

This financial incentive year on year would provide greater by-in of the retrofit SUDS programme identified and implemented by the local residents and stakeholders effected through the construction and disruption in the short term, ultimately caused to their roads and grassed areas.

The number of properties in Scotland in mid-2011 (General Register Office for Scotland 2013) was approx. 2.3million. With almost all of these properties paying the surface water drainage component of their wastewater charge, approximately £50 per property and two million properties, this generates £100million cost savings achievable annually, and certainly a thought provoking figure, one which will catch stakeholders attention.

There is insufficient detail in The City of Edinburgh Council’s bill to allow the average customer to determine which proportions of their wastewater charge is for foul drainage flows, property drainage and road drainage.

This lack of transparency means that there is no real financial incentive for customers to investigate, design, fund and implement a disconnection solution to their property.

The drainage utility and the local Council authority could provide literature, greater clarity and advice to customers defining the financial incentives available as supplied by other UK water companies and this lack of transparency means that customers are not empowered.

Other companies across the UK, supplying utilities services, such as gas and electricity to customers (Chapter 2.9), provide information and actively promote energy reduction schemes offering financial incentives to increase uptake.

7.7 SUMMARY

The largest expenditure the case study drainage utility faces is wastewater transport and treatment, see Chapter 2.8. By removing surface water prior to pumping will result in multiple benefits.

From the detailed drainage modelling conducted in Chapter 6, substantial data was obtained in regards volumes and durations of pumping station operation.

The information collected and collated was then analysed to assess the financial costs of the electricity consumed under the varying modelling and theoretical scenarios.

For the modelling scenario of 1 in 1Year with 60minute duration, the cost of power to transport the flows without surface water achieved a 83% saving of £1.69.

For the modelling scenario of 1 in 30Year with 60minute duration, the cost of power to transport the flows without surface water achieved a 91% saving of £3.41.

For the modelling scenario of 168storm events annualised, the cost of power to transport the flows without the surface water achieved a 87% saving of £230.

For the future vision of 2035, with the figures from 2010 and utilising the uniform series present worth with a 3.5 discount factor (Chapter 3.7.1) achieved an 87% saving of £3,791.

It is clear that there is a considerable difference between the energy cost for pumping the baseline flow and the dry weather flow however the absolute values of flow and money involved are low.

A desktop study was undertaken using the treatment train approach to investigate the financial implications of retrofitting a SUDS solution at the case study location. Construction, maintenance and whole life costs were examined and determined for each SUDS solution ranging from raingardens, swale, basin and associated pipework and included an alternative solution offered by some UK drainage utilities namely water butts. The costs incurred during the various stages of construction, maintenance and whole life costs of the swale, basin and pipework at £186,774 would be deemed in comparison to the annual financial saving of £230 on electricity costs alone to be cost prohibitive.

An expanded experiment was undertaken to investigate the cumulative impacts of sequential pumping flows. The financial data calculated showed the annual costs of electricity involving 168storm events and with the surface water removed for the scenario of multiple SPS's operating in sequence. These figures allowed the annualised savings over the 25year period of (87%), £3,790 at SPS1 and £136,454 at SPS8 to be achieved. These savings are achievable for the single wastewater system under investigation.

Investigating wastewater pumping stations currently operated by the drainage utility at the local level identified a number of significantly larger pumping stations. The key point is that these larger pumping stations will possess the same principles associated with conveying surface water to treatment however involve considerably large volumes and duration of operation such as demonstrated at the McDonald Road SPS which will result in higher energy consumption costs and thus potential savings.

The cost of electricity consumption at the pumping station investigated in the research experiment operates on a combined sewer flow pumping regime of 15l/sec which was activated only occasionally over 24hrs and as and when required.

The McDonald Road SPS in stark contrast is in continuous operation pumping 4,500l/sec, 24hrs and 365 days a year and is at the end of a series of consecutive pumps. It is hypothesised that the financial savings in electricity consumption identified and achievable at the local level could be extrapolated up to apply to larger SPS's such as McDonald Road SPS, to the national level across the 2,100SPS's and 315,360 megalitres, which the drainage utility operates and annually treats.

These findings highlight the considerable reductions which could also be achieved by any drainage utility when assessing SPS's at the national level.

The drainage utilities annual bill for power in 2011 was £40 million of which 71.8% is for grid electricity. 18.9% of the grid electricity consumed is for the conveying of flows through the wastewater system and 41.8% is for the 315,360 megalitres requiring wastewater treatment (Scottish Water 2011). The grid electricity expenditure incurred equates to £5,428,080 see Chapter 11.6 and £12,004,960 by the wastewater network and wastewater treatment processes respectively (Total £17,433,040).

When viewed across the 2,100SPS's currently in operation with many operating in sequence the significance of this research's findings become magnified and potentially quantifiable in millions of pounds as opposed to pounds and pence.

During storm events over 168 events annually, the flows being pumped were 90% surface water. If the surface water flows were to be removed then a high level approximate cost saving would range up to £15 million (90% of the total flow).

Householders can also benefit by removing surface water flows from the combined sewer system. As part of any UK household drainage utilities annual water and wastewater bill there is a breakdown of costs for the Water and Wastewater services which it provides. The wastewater component accounts for approx. 54% of the annualised bill (City of Edinburgh 2013) and includes a component for surface water drainage charge. However this bill does not provide a breakdown of the wastewater the services it provides, ie Roads and Property Drainage.

This surface water drainage charge, which accounts for approx. 10% of the total bill, has also been called the "Rain Tax" (Bennett 2011). Many UK drainage utilities now offer customer's incentive schemes to disconnect their surface water flows.

For the drainage utility investigated, and utilising the City of Edinburgh's available information, costs for each of the utilities services for a Band E property were shown to be Water £228.80 and Wastewater £265.54. The wastewater component is made up of 60% Foul, 20% Roads and 20% Roofs. These percentages were itemised as £159.32 Foul, £53.11 Roads and £53.11 for Roofs. If the customer decided to disconnect their roof drainage so that it was disconnected from the drainage utilities system a potential annual rebate of £53.11, (10.7%) could be achieved.

By investigating the number of potential properties incurring the "Rain Tax" estimated to be approx. 2.3million and £50 per property the significance of the findings is that if each of these properties were to disconnect their property drainage from the drainage utilities system a saving of approx. £100million could be achieved by the consumer.

The completion of these activities fulfilled the objectives of the financial examination exercises in Chapter 7.2.2 and 7.3.2 and 7.5.1. The financial analysis was carried out on the modelling, suds retrofit and theoretical findings in conjunction with the information obtained through the literature review and discussions with drainage professionals within the drainage utility such as at McDonald SPS. This communication and exchange of ideas and information fostered a greater understanding of how existing assets and infrastructure should transition in phases, to the proposed future state, by introducing sustainable water management techniques.

The financial figures calculated in this Chapter completes objective's 4, 5 and 6 and research aim 3 and provides further information and justification, to adopt and implement a suitable transitioning approach to achieve a more efficient and effective utilisation of wastewater assets and infrastructure.

CHAPTER 8 MONITORING

8.1 INTRODUCTION

This chapter describes the fourth of the main stages of the proposed transitioning approach and termed monitoring (Chapter 3.3.1), whose purpose is in process documentation, capacity building, evaluation and learning and the next round of transitioning (Fig 24) providing further information for objective 1 and justification for research aim 1.

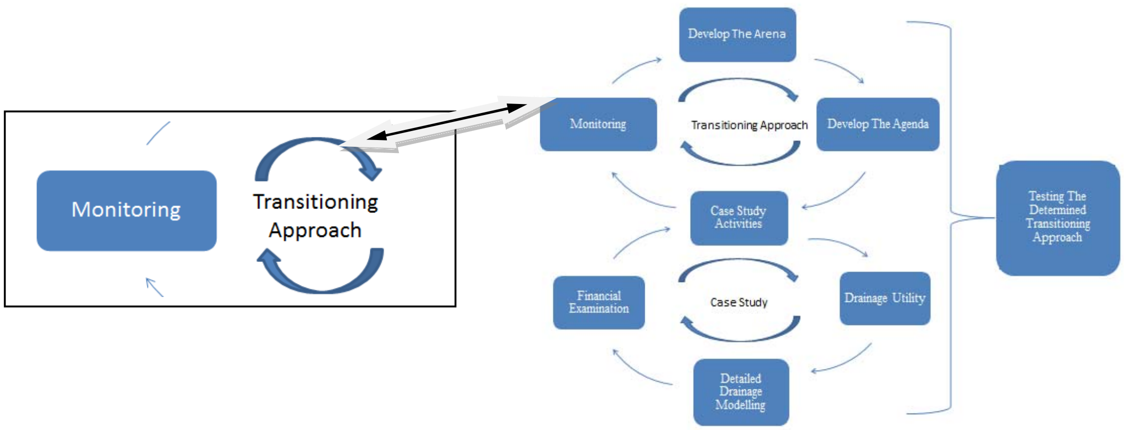

Figure 24 Monitoring Stage Of The Transitioning Approach

8.2 PROCESS DOCUMENTATION AND CAPACITY BUILDING

It is important to maintain excellent administration throughout the transitioning process. This accurate collection of data and subsequent reflection through regular reviews, presentations and reporting will identify levels of success (Olsson, Folke and Hughes 2008) of the items and objectives from the Transition Agenda.

Information can then be communicated to all parties involved, through meetings, workshops, publications, media outlets etc., (Pahl-Wostl 2009).

Capacity building is the communication and exchange of information obtained through research and current legislative and policy guidance documents between multi-actors and institutions in order to achieve the transition activity (Van de Meene 2008).

There is a transition occurring in the development of capacity building. The paradigm of educating and training individuals to improve a single organisation is being replaced by multi-stakeholder processes (Greijn 2010), to achieve wider sustainable development aims.

It is important to recognise that politics and power are intrinsically linked to any transitioning process and a significant shift in both is often required to bring about effective change (Woodhill and van Vugt 2010).

8.3 EVALUATION AND LEARNING

A period of reflection is required in order to review, evaluate and understand the reasons behind the successes or failures of the activities designated within the transition agenda and learn from them (Geels 2005).

As situations and circumstances change through ever evolving political and social pressures the transition process may be moving towards or further away from the originally identified vision (Keath and Brown 2008). It is imperative to recognise these subtle changes in policy or culture and respond through making decisions to alter direction as and when required.

8.4 NEXT ROUND OF TRANSITIONING

It is important to recognise the stages of the proposed transitioning approach and understand that it is indeed a cycle in that it is constantly moving and evolving. The participants engaged in the transition arena will be encouraged to discuss many of the positives and negatives of the research's findings creating the transition agenda.

Through this open discourse and exchange of ideas and views, a clearer picture of what is achievable and the impediments can become clearer. This approach also provides a platform whereby if a transition pathway needs to be altered in direction, the challenge could be identified, communicated, an alternative solution found and a different course chosen.

For the next round of transitioning much of the information with regards to stakeholders, and actors have been already been identified and it is up to the continuing participants driving the next cycle to maintain the gathering of interested parties, perhaps disentangle ineffective groups, reassemble sub-groups, revisit and refresh agendas and visions, always look to identify and support new champions in the arena.

8.5 SUMMARY

The monitoring chapter collates the evidence gathered through the previous transition approach stages (Fig 24). Information on theories, strategies, methodologies and findings from research and other advancements such as emerging policies and procedures can then be utilised to develop the new transition arena.

This stage was not selected for investigation and detailed analysis in the Case Study phase due to limitations of the research scope and time. Recommendations for future research topics to be carried forward to the next round of transitioning have however been identified in Chapter 11.6.

This stage also allows the evidence to be critically and peer reviewed to greater understand the successes and failures of the research conducted. The transitioning approach researched, developed and determined is cyclical. The transitioning cycle approach developed allows the information and evidence obtained to be entered into a new transition arena with new stakeholders possessing differing drivers to conduct the next round of transitioning.

These key activities provide further information for objective 1 and justification for research aim 1, to adopt and implement a suitable transitioning approach to achieve a more efficient and effective utilisation of wastewater assets and infrastructure.

CHAPTER 9 TESTING OF THE TRANSITIONING APPROACH

9.1 INTRODUCTION

This chapter addresses the testing of the transitioning approach (Fig 25). Utilising the information gathered in the literature review and examined in the preceding chapters, the next activity of the research was to organise and facilitate active discourse among the key stakeholders targeted and assembled. The research findings were presented to establish the level of success of the transitioning approach determined. The data obtained achieves objective 2 of research aim 1.

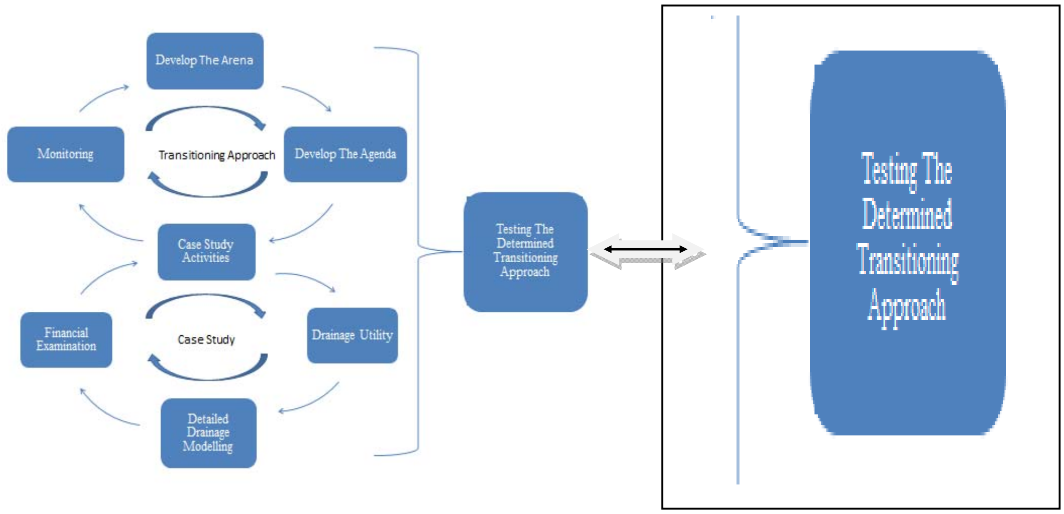

Figure 25 Testing The Determined Transitioning Approach

In order to collect informative data from the key stakeholders, the aims of the questionnaire must firstly be identified (Oppenheim 1996). These general aims must then progress to a determination of specific objectives or hypothesis (Chapter 1.3) to be investigated. The questions in the questionnaire were specifically designed, in order to make the analysis as comprehensive as possible (Miles and Huberman 1994).

A clear detail which has emerged throughout the course of this research is that effective communication and the exchange of ideas is vital to initiate any transition.

Arranging and facilitating workshops as well as meetings are an important part of communicating the latest research findings (Tiwari and Bandyopadhyay 2010), and to discuss the suitability of current policy and regulation. This focus allows the future research topics to be discussed, deliberated and collaborated on.

9.2 TESTING OF THE TRANSITIONING APPROACH - Objective

The objective of this chapter is to establish the level of success of the transitioning approach determined to reduce surface water volumes in combined sewer systems (Chapter 1.3). Presentations on the research hypothesis, the determination of the transitioning approach and the findings of the case study were given at convened workshops and meetings. Questionnaires were then completed to obtain information from the attendees on all of the research aims and objectives. The data was then examined to conclude the level of success as described in objective 2 of research aim 1.

9.3 TESTING OF THE TRANSITIONING APPROACH - Methodology

Of the five key stakeholder organisations identified (Chapter 5.2), only the drainage utility was proactively targeted. When collecting data it is often the case that it is not practicable to engage with all of the identified parties and this can be seen as a limitation in this research (Chapter 10.6.5).

Invitations to the research presentation were sent to personnel of the drainage utility under investigation. Personnel were identified through discussions with the research author as to their availability to participate. The meeting environment with participants arranged around tables in a circular fashion was selected by the researcher to encourage ease of discourse between participants.

At four separate meetings (Chapter 4.3), presentations of the research aims and objectives, examples of successful disconnection programmes, the modelling scenarios and financial examinations conducted and the transitioning approach is given, discussed and deliberated (See Appendix 2).

A questionnaire is then provided to the attendees to complete following the presentation in order to obtain their views and comments (See Appendix 2). The questionnaire consisted of five key points;

1. Surface Water
2. Stakeholders
3. Transitioning Approach
4. Transitioning Approach Solution
5. Research Hypothesis

There are a wide variety of methodologies available for use when presenting the collected data. These include Tables, Bar Charts, Graphs, Pie Charts, Comparative Pie Charts, Histograms, Pictograms, Comparative Pictograms, Cartograms or Map Charts, Strata Charts, Graphs, Semi-Logarithmic Graphs, Straight-Line Graphs, Gantt Charts, Break Even charts, The Z Chart, The Lorenz Curve, Stemplots, Scattergraphs, Time Graphs (Graham 1999), (Hannagan 1997) as well as text utilising percentages.

This research has utilised tables and percentages (Bar charts in Appendix 2) as the primary method of presenting information (Lewis 1999). Tables are a common method of displaying information to the reader in a clear yet basic level. Percentages are used to express numbers as a proportion and a technique widely used to convey messages of information including newspapers, journals.

The other methods stated previously which can be used for presenting data were discounted due to inappropriate utilisation and deemed by the research author to be secondary to the methods selected in delivering the evidence in a clear and concise manner.

9.4 TESTING OF THE TRANSITIONING APPROACH – Results and Discussion

9.4.1 Introduction

All of the 15 presentation attendees provided a response by completing the questionnaire. An introductory question was posed allowing the drainage utilities departments (Chapter 5.3.2) to be identified and to ease the respondents into the questionnaire.

Table 23 Responses For Question 1.

Department	No. of Respondents
Asset Infrastructure Management	2
Finance	2
Energy	1
Administration	0
Legal	0
Environmental	0
Commercial	8
Policy and Regulation	1
Customer Connections	0
Operations	1

Question 1. Which departmental description best describes where you work?

The respondents were all experienced wastewater industry professionals with the majority of participants from the commercial division (Table 23). This allowed a greater insight to be obtained in regards the financial focus of the research into reducing energy consumption at SPS's by removing surface water.

9.4.2 Surface Water

A series of questions were posed to the presentation attendees regarding surface water and the implications of removing these flows from the combined sewer system. The questions were designed to provide supporting and justifiable information to the research aim 2 and 3 directly.

Table 24 Responses For Questions 2 and 3.

Response	**No of Respondents**	
	Question 2	**Question 3**
Yes	15	15
No	0	0
Neither Yes/No	0	0

Question 2. Do you think surface water flows in the combined sewer system should be removed? And **Question 3.** Do you think surface water flows in the combined sewer system should be reduced?

The responses from Question 2 and 3 identified that 100% of the respondents were in agreement that surface water should be removed from and reduced in combined sewer systems (Table 24). These questions and responses provide evidence supporting the novel transitioning framework approach developed as described in Chapter 4.4.

The responses from Questions 4, 5, 6 and 7 are shown in Table 25.

Table 25 Responses For Questions 4, 5, 6 and 7.

Response	**No of Respondents**			
	Question 4	**Question 5**	**Question 6**	**Question 7**
Strongly Agree	6	8	9	7
Agree	7	4	6	6
Neither Agree nor Disagree	2	3	0	2
Disagree	0	0	0	0
Strongly Disagree	0	0	0	0

Question 4. Do you think the removal/reduction of surface water would provide financial benefits?

87% of respondents agreed that there would be financial benefits to be achieved from the removal/reduction of surface water flows from the combined sewer system. 13% of the respondents were neither in agreement nor disagreement (Table 25). These responses provide supporting information to achieve research aim 2. The information obtained is also linked to objective 4 concerning the financial savings achievable, objective 5 the financial expenditure incurred and objective 6 the financial implications at the local and national level.

Question 5. What do you think about the following statement: The removal of surface water from the combined sewer system prior to pumping is a necessity not a luxury?

No respondents disagreed with the statement, 53% strongly agreed and 27% agreed (Table 25). Only 20% of the respondents were neither in agreement or disagreement. The responses obtained provide supporting information to the research hypothesis and overarching goal of the research (Chapter 1.3).

Question 6. Do you think the removal/reduction of surface water would provide environmental benefits?

All of the respondents agreed that environmental benefits would be provided through the removal of surface water flows from the combined sewer system (Table 25), with 60% strongly agreeing. The information obtained provided supporting evidence to assist in achieving objective 1.

Question 7. Do you think the removal/reduction of surface water would provide social benefits?

The potential for social benefits was put to the participants (Table 25). 47% of the respondents strongly agreed with the principle that the removal/reduction of surface water from the combined sewer system would provide social benefits. 40% of the respondents similarly agreed that there would be social benefits which could be achievable. Two of the respondents were undecided as to whether there would be a positive or negative effect from the transitional utilisation of wastewater assets and infrastructure. Similar to Question 6, the information obtained provided supporting evidence to assist in achieving objective 1.

9.4.3 Stakeholders

Key stakeholders involved in the decision making process have been identified within the literature review and are described in the Develop the Transition Arena stage of the developed transitioning framework (Chapter 4.2.1). The questions were designed to provide supporting and justifiable information to research aim 1. Questions were posed to the attendees to provide a greater understanding of who personnel within the drainage utility, itself being a key stakeholder (Chapter 5.3.2), understood to be the decision makers in producing and implementing policies in removing/reducing surface water flows from the combined sewer system (Objective 2).

Table 26 Responses For Questions 8 and 9.

Response	No of Respondents	Ranked by Respondents [x]
	Question 8	Question 9
Water Industry Commissioner for Scotland	15	3
Scottish Government	15	1
Customer Focus Scotland	11	5
Scottish Water	14	2
Scottish Environment Protection Agency	14	4
Everyone	11	---

[x] The ranking of respondents were conducted using the mode approach (Graham 1999) where 1 is the most important and 5 the least important, see Appendix 2.

Question 8. Who do you think is responsible for reducing surface water flows, please tick more than one if necessary?

The respondents recognised the Water Industry Commissioner for Scotland, Scottish Government, Scottish Water and SEPA as being the primary stakeholders responsible (Table 26). The second level was Consumer Focus Scotland and an overall recognition that everyone had a responsibility. With the key stakeholders being identified (Chapter 5.2) the responses to Question 8 provided information to assist in achieving objective 2.

Question 9. Of the key stakeholders identified, please rank them in order of importance of making the ultimate decision to implement the Disconnection Rebate Scheme? 1 is the most important with 5 being the least.

Following the identification of the levels of responsibility of stakeholders in Question 8, the participants were asked as to rank their individual importance in regards making a decision to implement a disconnection programme (Table 26). The Scottish Government was identified as the ultimate decision maker followed by Scottish Water, the Water Industry Commissioner for Scotland, SEPA and Consumer Focus Scotland. The data obtained from the respondents in answering Question 9 provided information to assist in achieving objective 6.

9.4.4 Transitioning Approach

The transitioning approach identified within the literature review see Chapter 2.2 was presented and discussed during the meetings prior to the questionnaire. The questions were designed to provide supporting and justifiable information to the research aims and objectives.

A number of questions were then put to the respondents to obtain their views as described in objective 2 whether the approach put forward to remove surface water flows from the combined sewer system was appropriate and indeed even necessary.

Table 27 Responses For Questions 10, 11, 13.

Response	No of Respondents		
	Question 10	Question 11	Question 13
Strongly Agree	7	4	9
Agree	7	9	6
Neither Agree nor Disagree	1	2	0
Disagree	0	0	0
Strongly Disagree	0	0	0

Question 10. Do you think removing surface water from customer's properties through the Disconnection Rebate Scheme is a key transitional step to achieving the vision of surface water free pumping stations?

None of the respondents disagreed that the disconnection programme (Table 27), currently being implemented by other drainage authorities in the UK following the Pitt review (2008), (Chapter 7.6) could be seen as a transitioning step to achieve surface water free pumping stations. 47% of the respondents strongly agreed with the question whilst a similar 47% agreed. Similar to Question 9 the findings from Question 10 provide supporting information to assist in achieving objective 6.

Question 11. Do you think the Transitioning Management Cycle is the correct approach to achieve the vision of surface water free pumping stations?

The Transitioning Management Cycle presented received a positive agreement from the participants (Table 27). From the respondents 27% strongly agreed the transitioning management cycle was the correct approach, whilst 60% of the respondents were in agreement. The data from the responses to Question 11 provide supporting information to assist in achieving objective 1. One of the respondents highlighted that other approaches may also be appropriate and logical.

Table 28 Responses For Question 12.

Factors	Respondents Ranking×
Financial	1
Environmental	3
Legislation	2
Political	4
Health and Safety	5
Social	6

× The ranking of respondents were conducted using the mode approach (Graham 1999) see Appendix 2.

Question 12. Please rank the factors that would influence you the most in supporting a project removing the surface water flows from the combined sewer system with 1 being the most influential to 7 being the least?

The workshops, meetings and presentations discussed a variety of influencing factors faced by the drainage industry professionals when delivering their own projects (Table 28). Financial factors were identified by the respondents as the most important influencing factor. Legislative and Environmental considerations were the second and third most important. Political, Health and Safety and Social factor were deemed to be of least significance from the several of options presented.

Similar to Question 11 the findings from Question 12 provide supporting information to assist in achieving objective 1. One of the respondents advised that sewer flooding should be on the list and that it contained both a social and a health and safety component.

Question 13. Is a transition in the operation and utilisation of wastewater assets and infrastructure required?

A foundation principle of the research is that a transition in the operation and utilisation of wastewater assets and infrastructure is required (Brown, Farelly and Loorbach 2013). The justification for this principle was tested on the participants to see if the research author's aims and objectives could be substantiated.

All of the respondents i.e., 100% were in agreement with the research's foundation principle (Table 27). There were 40% of the respondents who agreed whilst the majority at 60% strongly agreed that a transition was required. These findings provide additional evidence that the research area is worthwhile. One of the respondents suggested a further research experiment should be undertaken into calculating the surface area of Scotland which is covered by roof space and comparing this with the surface area of urban areas where surface water runoff goes to WwTW's.

9.4.5 Transitioning Approach Solution

A series of questions were posed to the respondents to provide an understanding of whether or not the transitioning approach, to reduce surface water flows from the combined sewer system, presented would be necessary, appropriate and successful. The results obtained provide supporting information to assist in achieving research aim 1.

Table 29 Responses For Questions 14, 15 and 16.

Response	No of Respondents		
	Question 14	Question 15	Question 16
Strongly Agree	7	9	0
Agree	7	5	12
Neither Agree nor Disagree	1	1	2
Disagree	0	0	1
Strongly Disagree	0	0	0

Question 14: Do you think an incentive scheme is necessary?

Complimentary to the response from the respondents that a transition was required in Question 13, the vast majority of respondents agreed that an incentive scheme (Chapter 7.6) was necessary in order to bring about transition (Table 29). There was an equal percentage return from respondents with 47% agreeing and 47% strongly agreeing that an incentive scheme was indeed necessary. The data obtained provide supporting information to assist in achieving objective 1.

Question 15: Would you support the removal of surface water through the Disconnection Rebate Scheme?

The drainage industry professional's engaged with wholly supported a potential disconnection scheme (Table 29). There were 60% of the respondents who strongly agreed with the approach supporting the findings identified in Chapter 2.4.4. The results obtained provide supporting information to assist in achieving objective 6.

Question 16. Do you think a Disconnection Rebate Scheme would be successful?

Following on from the support obtained to Question 15 regarding a potential disconnection scheme, the participants were asked whether they thought such a scheme would be successful. The results in Table 29 demonstrate the significant majority of the respondents at 80% were in agreement that the disconnection scheme would be a success. These responses provide additional information to assist in achieving objective 6

9.4.6 Research Hypothesis

The research hypothesis (Chapter 1.3) and the research findings were presented to the attendees. The questions were designed to provide supporting and justifiable information to achieve the overarching goal of the research.

Table 30 Responses For Questions 17 and 18.

Response	No of Respondents	
	Question 17	Question 18
Strongly Agree	6	9
Agree	6	5
Neither Agree nor Disagree	2	1
Disagree	1	0
Strongly Disagree	0	0

Question 17. Do you think that the removal of surface water from a typical combined sewer system is justified by focusing on the energy consumption required to pump increased volumes during storm events and applying a transitioning approach.

The attendees identified that the removal of surface water from the combined sewer system was justified by applying a transitioning approach and focussing on the energy consumption savings at the investigated SPS (Chapter 1.3).

The majority of respondents (Table 30) agreed with the research hypothesis, 40% strongly agreed and 40% were in agreement. One respondent disagreed and requested further information.

Question 18. Do you think that the removal of surface water from a typical combined sewer system is justified by focusing on energy consumption, the potential financial, environmental, social benefits achievable and applying a transitioning approach, see Chapter 3.3.1.

The justification of the main principles of the research was concluded within Question 18, (Table 30). The respondents provided proof to the research hypothesis that the removal of surface water from the combined sewer system was even more justified than in Question 17 by applying a transitioning approach and focusing on the energy consumption when addressed with the other potential benefits achievable. 93% of the respondents were in agreement with 60% strongly agreeing, 33% in agreement with only 7% who were undecided.

9.5 SUMMARY

9.5.1 Introduction

With the key stakeholders in this research being identified, it was important to organise and facilitate the attendees in a manner conducive to allow free and open discourse on research, innovative ideas and on new and existing technologies.

Providing suitable environments as discussed in Chapter 4.3, to conduct meetings, workshops, conferences is vital to encourage participants to exchange ideas, views, drivers, policies and opinions.

Utilising the information obtained in the previous chapters the transitioning approach determined was presented to a variety of personnel within the drainage utility and tested utilising the questionnaire methodology.

The main aim of these meetings was to present the research, effectively communicate the findings and encourage discussion with the participants. Consideration was given to interviewer bias when conducting the questionnaires (Oppenheim 1996).

Measures were adopted to mitigate any undue influences by being prepared prior to the presentation, remaining impartial during discussion and taking cognisance that questions should be clear and delivered consistently and dispassionately (Saunders, Lewis and Thornhill 2012). Data was then obtained through the completion of a questionnaire to assist in the determination of an effective transitioning approach.

Key sections of the questionnaire, provided to participants, included surface water, stakeholders, transitioning approach, transitioning approach solution and research hypothesis.

9.5.2 Surface Water Summary

All of the respondents agreed unanimously that surface water flows should be removed as well as reduced from the combined sewer system thus forming a key proof of the transitioning approach determined in this research (Chapter 4.4).

This finding is particularly relevant as the economic case (Chapter 10.5) is not considered strong at the local level and significant as the respondents agreed this was the way forward. In keeping with these findings the majority of respondents also agreed that removing surface water prior to pumping was a necessity not a luxury.

The majority agreed that there would be financial, environmental and social benefits to be achieved through the removal of surface water from the combined sewer system. One respondent commented that additional detail would be necessary on the non-cost benefits. None of the respondents disagreed with the principles of the research.

One of the undecided respondent's requested further expansion of the research, in line with the principles of the Monitoring stage of the developed transitioning framework (Chapter 8) into the subject area to provide more information prior to making a more decisive appraisal of the findings. One of the respondents stated that consideration should also be given to ground saturation and impact on receiving watercourses.

9.5.3 Stakeholders Summary

Key stakeholders are identified in the Develop the Transition Arena stage of the transitioning framework developed (Chapter 4.2.1). The presentation was given to attendees described in the Case Study Drainage Utility stage (Chapter 5.2). The questions were delivered to provide a greater understanding of who the participants understood to be the decision makers in producing and implementing policies in removing/reducing surface water flows from the combined sewer system (Chapter 5.3.2).

The respondents identified that although the Scottish Government came out top closely followed by the drainage utility they saw no one clear stakeholder as being responsible and the feedback was generally that everyone had a role to play.

The attendees remarked that the local council authorities and the drainage utilities own customers should have been on the list of those responsible. The responses provided supporting and justifiable information to achieve research aim 1 and objective 2.

9.5.4 Transitioning Approach Summary

Questions were put to attendees to obtain their views whether a transitioning approach to remove surface water flows from the combined sewer system was appropriate and indeed even necessary. The transition management cycle which provided the basis of the novel transitioning approach developed in this research (Chapter 3.3.2), was understood to be an appropriate mechanism to achieve transition.

The significant majority of respondents agreed that a transition was required. The disconnection programme was identified as an achievable step to achieve a transition. One attendee suggested that piloted geographical studies should be conducted to carry out a cost benefit analysis of such a programme. Another suggested the drainage utility should provide water butts to customers agreeing to the disconnection rebate scheme free of charge. The respondents highlighted that the financial implications of such a transitioning approach would be the most important with social considerations the least and that sewer flooding incidents could be added.

9.5.5 Transitioning Approach Solution Summary

Attendees were provided with questions to obtain an understanding of whether or not the transitioning approach developed (Chapter 4.1), and presented would be necessary, appropriate and successful. The respondents made a clear statement that they understood a disconnection rebate scheme was required (Chapter 2.5.1), it would be successful and that they would support it if it came into fruition.

One of the respondents suggested that housing and industrial developers should be required to fund the separation of existing combined sewer flows in order to mitigate against their developments thus negating the impact of urbanisation. Another potential solution proposed was to look at using roof water for toilet flushing thereby reducing the water demand with no net increase in wastewater discharge.

9.5.6 Research Hypothesis Summary

Two key questions were posed to the presentation attendees at the end of the questionnaire. These questions focused on providing feedback on the level of success of the research hypothesis (Chapter 1.3).

Under investigation is that the removal of surface water from a typical combined sewer system is justified by applying a transitioning approach and focusing on the energy consumption required to pump increased volumes during storm events (Chapter 4.1).

The respondents to Question 17 with knowledge of the economic position and contrary to reporting that finance (Question 4), was their most influencing factor stated their agreement with the research hypothesis. The attendee's responses confirmed that the removal of surface water from the combined sewer system was justified by applying a transitioning approach and focussing on the energy consumption savings at the SPS investigated.

The respondents to Question 18 provided further evidence by strongly agreeing that when other potentially achievable benefits (Chapter 2.6), were also utilised in the justification process to remove surface water from the combined sewer system that they would be even more supportive.

9.5.7 Conclusions

The completion of these tasks fulfilled the objective of the testing of the transitioning approach (Chapter 9.2).

From the exercise conducted it is clear the majority of wastewater industry professionals engaged with, provided substantial evidence they agreed with the research principles that the pumping of surface water flows prior to treatment was unnecessary and a transition in the utilisation of wastewater assets and infrastructure was justified based on the benefits achievable.

The attendees agreed (Question 17), that the removal of surface water from a typical combined sewer system is justified by applying a transitioning approach and focusing on the energy consumption required to pump increased volumes during storm events (Chapter 4.1).

This position is significant as it is in direct contrast to their previous position about finance being the most influential consideration and the weak economic case (Question 12).

The data gathered using the questionnaire process possessed some inherent limitations (Chapter 10.6.4). Primarily the research testing Chapter was limited by its small sample size. In addition the sample of respondents in this research was also only taken from one stakeholder. Findings from a small group of participants can often be viewed as skewed or unrepresentative (Hannagan 1997). This research has fallen into one of the most common pitfalls to befall field researcher's which is the sampling of non-representative informants, the error ultimately being an overreliance on accessible and elite informants (Miles and Huberman 1994).

The results obtained from all of the 15 attendees should not be taken as a genuine representation of the identified stakeholders (Chapter 4.2.1), nor the drainage utility investigated as a whole due to the level of significance the subset of respondents possess (Chapter 3.10) (Bryman and Bell 2011). Moreover the relationships between this subset and the wider organisation should be further investigated before claiming causality to avoid a spurious association (Easterby-Smith, Thorpe and Lowe 2004).

When presenting collated data and regardless of whichever method is adopted; tables, percentages or bar charts the principle is to summarise and simplify the central points which will assist in the decision making process. However it is possible to oversimplify and present the information in a misleading or perhaps ambiguous manner resulting in difficulties of perception, distortion and deception (Graham 1999).

For future research (Chapter 9.1 and 10.6.3) a more representative sample of stakeholders needs to be taken and expanded to obtain comments and views from key personnel within those organisations.

Similarly a greater emphasis in collecting data in this section by an earlier engagement with the identified stakeholders would be beneficial in surveying a greater number of participants and organisations.

A larger sample of respondents with more diversity would have benefited the results (Hannagan 1997) and ideally the respondents would have been from decision making positions of key stakeholders organisations.

The case studies main sections (Chapter 1.2) are a drainage utility, detailed drainage modelling and financial examination. The findings from this research case study has identified that multiple benefits are readily achievable to a wide range of stakeholders by removing surface water from the combined sewer system.

The findings possess a wide scope for exportability to other departments within the drainage utility under investigation, different drainage utilities and other utility organisations (Chapter 11.2) with similar and varying scenarios utilising detailed drainage modelling with subsequent financial examinations.

The drainage utilities departments such as Networks, Assets and Finance will benefit through achieving improvement drivers such as reduced flooding incident's, reduced combined sewer overflows and a decrease in CAPEX and OPEX (Chapter 5.3.2).

The same operational challenges faced by other drainage utilities will therefore possess the potential to achieve similar improvement drivers, whilst other utility organisations have the potential to benefit from implementing innovative and incentive schemes for their customers (Chapter 2.5.2).

The transitioning framework developed within this research focused on the levels of electricity consumption consumed by a drainage utility to transport surface water flows to treatment as the improvement driver under investigation.

An alternative improvement driver (Chapter 5.3.2), could just as easily be selected and used as the focus of the research (Chapter 11.2), instead to identify the multiple benefits readily achievable to the pertinent stakeholder at the local and national level.

Further research into achieving improvement drivers particularly concerning the transition from the previously accepted practice of wastewater transportation and existing paradigm to a more sustainable paradigm which achieves a more efficient utilisation of wastewater assets and infrastructure is fundamentally required (Chapter 2.2), and should be encouraged and supported. This chapter testing the determined transitioning approach (Fig 25) completes objective 2 of research aim1.

CHAPTER 10 DISCUSSION AND CRITICAL EVALUATION

This chapter discusses and critically evaluates the main themes of the research, identifying the methodologies investigated, utilised and discounted, the key stages and tasks conducted, results obtained and the conclusions drawn.

The research aims to advance the knowledge in the field of urban drainage, by providing justifiable information, to support the removal of surface water from combined sewer systems through the identification, determination and utilisation and testing of an effective transitioning approach.

10.1 INTRODUCTION

This research is the first to look at justifying the reduction of surface water flow's in combined sewer systems by conducting these three key tasks specifically;

1. Developing an appropriate transitioning approach to provide a more effective and utilisation of wastewater assets and infrastructure by identifying key stages and requirements.

2. Investigating the levels of grid electricity consumed at sewage pumping stations through conducting detailed drainage modelling and financial examinations, identifying and determining the costs incurred and the benefits achievable.

3. Convening workshops, meetings delivering presentations to obtain evidence from key stakeholders to test the success of the transitioning approach determined and adopted.

The available literature on transitioning, transitioning theory and transitioning approaches were researched. This investigation identified successful examples of surface water removal focusing on the reduction and attenuation from combined sewer systems by implementing innovative solutions and the methodologies to test the effectiveness of the determined transitioning approach.

10.2 DETERMINATION OF A SUITABLE TRANSITIONING APPROACH

Transitioning can be seen to occur in all aspects of society as presented by Bergman et al (2008) through embracing the emergence of innovative ideas and the adoption of alternative techniques and methodologies supported by Jansen (2005), such as demonstrated in the field of transport with electric/dual fuel cars and communication and applicable devices with the increase in wifi and broadband connection capability.

In addition to transitioning being seen to occur, it is also reported by Loorbach and Rotmans (2006) to ultimately be inevitable and needed, a view similarly held and reported in the innovation for sustainable development: from environmental design to transitioning management paper by Mulder (2007).

There will be a driver for change behind every transitioning step. Whether the driver for change is achieved or proposed, ultimately transition is down to personalities, people, planning, politics and purses as described by Brown, Farelly and Loorbach (2013).

Currently significant volumes, 315,360 megalitres annually, of combined sewer flows including surface water are pumped considerable distances at great expense (Chapter 8.5.3) prior to treatment by the drainage utility under investigation (Scottish Water 2011).

With increased knowledge of the transitioning steps identified throughout this literature review, selecting the “Do nothing” approach in regards investigating, designing and implementing retrofit projects to remove surface water from the combined sewer system will be unacceptable to the decision makers.

In order to support this transition, effective and justifiable research needs to be undertaken, communicated and through the development of a transition framework, key stakeholders and actors can be identified and engaged.

This fundamental understanding which is adopted in this research is also supported by Gill (2008), whose report on Making Space For Water, Urban Flood Risk And Integrated Drainage similarly conducted workshops to obtain stakeholders opinions. Gill (2008) concluded that any organisation can contain individuals who possess the necessary skills and drive to lead integrated drainage work and ultimately bring about change.

The transitioning theory put forward and under investigation in this research is supported by Bergman et al (2008), which highlights the interdependency of institutions and assets and that it is not possible with current techniques to transition from the existing inefficient paradigm to a paradigm more sustainable for all stakeholders whereby existing assets and infrastructure will be different and incur a lower energy cost of operation.

A view similarly supported by the Green Ribbon Political Awards programme and the Jack Lewin Prize as discussed by Juniper (Juniper 2014) and Yarrow respectively in The Environment magazine (Yarrow 2014a) praise’s projects and personnel who demonstrate improving community collaboration and promoting stakeholder engagement to bring about successful partnerships to achieve even better results.

The transitioning approach developed throughout this research involving the numerous stages has been determined by the testing chapter (Chapter 9.5.7) to be successful.

10.2.1 Transitioning Approaches

The available literature reviewed during this research (Chapter 2.2) provided a greater insight into the numerous transitioning frameworks, approaches and methodologies available for selection to achieve the research aims and objectives.

Papers such as the sustainable water management in the city of the future, SWITCH Urban Water (2013), attempted to generate discourse on the most appropriate transitioning approach to bring about switching from "here to there" by identifying topics and encouraging debate on the issues and challenges, stakeholder influences and barriers to retrofitting.

The strategies which could potentially achieve the research aims and objectives such as the Urban Water Management Transition Framework by Wong and Brown (2009), the Steps to Successful Change by Kotter and Rathgeber (2006) and the Transitioning Framework by SWITCH Urban Water (2013) were identified, reviewed and critically evaluated for suitability.

The Urban Water Management Transition Framework provides a series of improving development stages towards achieving the vision of an efficient, optimised and sustainably integrated water city of the future (Wong and Brown 2009).

The approach allows the practitioner a visual tool to identify where they are and where they want to be. The conceptual approach to transitioning from Wong and Brown (2009) has been adopted by this thesis, however a more specific and detailed approach was utilised in order to address the research aims and objectives.

Steps to successful change as identified by Kotter and Rathgeber (2006) provide clear information and methods particularly in regards how the reader should attempt to set the scene, the conviction required in regards making and influencing decisions and decision maker's.

This direct approach in achieving and completing specific tasks also demonstrates the key ingredients to any successful transitioning process combined with the quality of perseverance to keep going, the latter, of which was utilised throughout the various challenges faced with completing this research. The steps identified are general and could be applicable to the transformational processes affecting many aspects of products, goods and services.

The approach developed, presented, determined and tested see Chapter 9 incorporates and improves on the key steps and tasks identified in Table 1, by Kotter and Rathgeber 2006. The approach builds upon the urban water management transition framework proposed by Keath and Brown (2008) and adopts the principles of the transitioning approach by SWITCH Urban Water (2013) producing a methodology which clearly identifies and outlines the necessary steps to establish and define the issues.

The Determined Transitioning Approach

Upon completion of these key steps and tasks, stakeholders were identified and engaged, meetings held, presentations given and questionnaires conducted to test and establish the success of the determined transitioning approach see Chapter 3.3.1 and Figure 11.

Develop the Arena

The similarities within these transitioning framework approaches (which identify steps to successful change) are that they all require the identification of key stakeholders, development of an arena (Chapter 4), communicating and engaging with organisations providing understandable information such as reported by CIRIA 2011 and the West Lothian Council (2009) to the parties identified and involved.

Essential to any successful transitioning process is the identification of the decision makers, i.e., the key stakeholders, as a separate group from other stakeholders/actors who possess opinions yet can only influence the actual decision makers as demonstrated by the successful surface water disconnection programme conducted in the City of Ann Arbor (2007).

It involves all of the parties allowing the communication of research and findings to be delivered in an effective environment to bring about the dialogue necessary to influence the decision makers and ultimately accomplish a change in direction or focus as reported by Jefferies and Duffy (2011).

<u>Develop the Agenda</u>

The approach selected involves the development of an agenda (Chapter 4.3), identification of and communication to a wide range of stakeholders the importance of which was highlighted by DEFRA (2007), including environmental organisations and residents associations such as supported by Hottenroth (2008). Following the key stakeholders identification it was then important to investigate and determine what each group's drivers were (Lencd 2013).

Stakeholders will possess differing drivers as put forward by Ellis et al (2006) budgets and priorities, short to long term, will be related to financial, political, social and environmental concerns amongst others and through greater communication it's important to clearly identify the issues, obstacles and the challenges faced by each stakeholder described by Hemmati (2010).

Bayliss (2009), discussed Welsh Water's surface water management strategy whose aims and were, similar to this research, to remove and deter surface water from entering combined sewer systems. Their strategy also looked to decrease energy costs and carbon emissions, reduce future flooding/pollution and to counter detrimental effects of increase urbanisation.

The latter is currently a particular contentious issue in urban areas (Vrijthoff 2007). Within high density areas such as in London as reported by the Environment Agency described in their (2007) Science Report – SC0600024 that increased housing and climate change problems will only become worse as exhibited in the understanding that as soon as specific flooding problems and issues are fixed, others will develop resulting in different challenges particularly through increased housing and homeowners desire to convert front gardens into car parking spaces (Wright et al 2011).

Similarly there will be differing barriers and drivers to the implementation of urban drainage improvement works specifically SUDS which will be pertinent to varying stakeholders as discussed and described by Bastien, Arthur and McLoughlin (2012).

Communication strategies should be delivered by frontrunners and champions identifying beneficiaries, presenting demonstration sites, conducting extensive media campaigns and promotional literature. There were no media campaigns (Chapter 4.3.1) produced for this research due to time constraints.

However successfully conducted consultations utilising similar principles as adopted in this research are demonstrated and expanded upon by the City of Ann Arbor (2007) who carried out a wide public consultation process to engage and obtain support from the local community.

Experimentation (Case Study)

The transitioning required now is an example of an issue possessing a number of barriers as discussed by Frantzeskaki and Loorbach (2008) (Chapter 2.2), however many surface water improvement programmes encountering similar obstacles have successfully overcome these challenges through transitioning path experiments.

Transitioning path experimentation (Chapters 5, 6 and 7) is fundamental to build upon previous research and ultimately improve and advance the understanding of the knowledge base embedding the information and principles collected and determined within larger innovation networks in order for key stakeholders and decision makers to prioritise infrastructure improvement projects and programmes as put forward by Van der Brugge and Rotmans (2006).

Surface Water Removal/Attenuation

Examples of successful implementation and realisation of surface water removal/attenuation solutions, completely separate systems of drainage, retrofitting SUDS and installing green infrastructure across the world were investigated and identified (Chapter 2.4).

Ranging from Water Urban Design Programmes placing water at the centre of the urban design process such as in Melbourne, by Melbourne Water (2013), introducing separate systems of drainage in the Emscher Basin, Germany by Becker et al (2006), SNIFFER (UE3(05)UW5 (2006), disconnection rebate schemes - City of Portland, USA by Hottenroth (2008), (Adderley 2007), and Augustenborg, Malmo, Sweden by Kazmierczak and Carter (2010), retrofitting SUDS in Tokyo, Japan by Fujita (1997) Tower Hamlets, London, Susdrain (2015a) and in Nottingham, UK Susdrain (2015b), too installing green infrastructure in Philadelphia, Washington DC, California, and New York, USA described by Foster, Lowe and Winkelman (2011), and Freiburg and Berlin, Germany in The Green Infrastructure (2010) and by The Green Roofs (2011).

The Portland Disconnection programme (Portlandonline 2014) targeting homes and small businesses with combined sewer systems, serves as an exemplar location whereby property owners received $53 per disconnected downspout. From its inception in 1994, the program involving 56,000 properties as reported by Adderley (2007) had successfully removed 1.2 billion gallons from entering the combined sewer system. This transitioning approach successfully utilised many of the research activities to identify an appropriate strategy to engage and communicate with stakeholders as put forward by this research approach.

The first step albeit contrary to this research approach's process as their target audience was already known was however to educate the local jurisdiction, residents and businesses providing advice on simple steps to disconnect downspouts, Portlandonline (2014) addressing improvement drivers and environmental considerations including the impacts of energy consumption and climate change achievable through stormwater fee discounts, development incentives (De la Rue du Can et al 2014), grants, rebates and installation financing including awards and recognition programs.

Further examples such as the Interreg III B – project Urban Water (Jefferies and Duffy 2007) similarly identified objectives to this research and demonstrated improving partnerships between stakeholders, conducting pilot projects disseminating results and findings will result in the improvement drivers for transition being realised.

A common theme of all of these projects is they demonstrate the fundamental principle of a real positive movement along the transitioning process and that change can and will happen with innovative strategies, new ways of thinking and focus upon differing priorities. Including energy consumption and climate change as addressed by Crane et al (2012), and opposed to the traditional and historical method of swift conveyance thus supporting the overarching goal of this research.

UK Drainage Utilities

In contrast to the above however the drainage utilities of the UK provide numerous examples of continuing with tried and tested solutions to alleviate issues as demonstrated by Ashley et al (2011) despite alternative and innovative solutions and strategies being widely available with missed opportunities identified successfully elsewhere as reported by Evans (2014).

The project by Severn Trent (NCE 2010) to improve the water quality of the receiving watercourse involves constructing 20,000m³ of below ground reinforced concrete storm sewage to attenuate flows to reduce the annual sewage overspills to the River Tame purportedly by 75% from 153,000m³ to 33,000m³. However this project, at £7.5 million will still incur full treatment costs at the wastewater treatment works demonstrating a reliance of last century engineering practices and a lack of acceptance of innovation.

Symbolic of this last century way of thinking, the drainage utility involved in this investigation has recently announced a £3.5 billion investment programme to improve services for the period 2015 - 2020 and ratified by all key stakeholders as reported by the BBC (2014) incorporating a borrowing of £720million from the Scottish Government. Included within this financial expenditure, there are wastewater projects highlighted such as:

1. Over £100million for a Glasgow wastewater tunnel to improve the water quality in the River Clyde and reduce flooding.
2. £45million to address 400 external sewer flooding problems
3. Over £60million to reduce the impact of discharges to the River Clyde from the Daldowie and Dalmarnock Wastewater treatment works

The projects as identified above, once completed, will provide considerable improvements to the combined sewer system, benefiting the receiving environment and society.

Despite the benefits achievable and contrary to the scope of this research, the methodology behind the practice of wastewater transportation remains the same as previous generations and is preoccupied with flow volumes or rates a view supported by Ashley et al (2011).

The practice continues to construct not only larger underground sewer structures to convey the flows as quickly as possible to treatment, but to provide even greater storage tanks at the WwTW to accommodate the increase in flow.

Monitoring

An important component of the transitioning approach adopted is effective process documentation and capacity building through post project monitoring which requires excellent record keeping and administrative duties to ensure information can be communicated effectively to all parties identifying levels of success as described by Olsson, Folke and Hughes (2008) of the items and objectives from the Transition Agenda.

Capacity Building concerns the communication and exchange of information obtained through research and current legislative and policy guidance documents between multi-actors and institutions in order to achieve the transition activity as reported by Van de Meene (2008).

There is a transition occurring in the development of capacity building. The paradigm of educating and training individuals to improve a single organisation is being replaced by multi-stakeholder processes a point raised and discussed by Greijn (2010) to achieve wider sustainable development aims.

This view is also supported through the emergence of the changing paradigm in urban stormwater management in Australia as described by Wong and Brown (2009), which is reflected in the considerable advances that have taken place since this key note address was delivered with the emergence of notably water sensitive urban design (WSUD) by Brown and Clarke (2007) amongst others.

10.3 CASE STUDY – DRAINAGE UTILITY

The key stakeholders interconnecting with the drainage utility were identified in Chapter 5. Each of the key stakeholders investigated possess improvement drivers. Improvement drivers for the drainage utility were identified and include financial, environmental and social considerations. These drivers are challenging to monetise and requires further research than has been conducted here to greater understand the full benefit.

Other drainage utilities may possess differing improvement drivers however they will all follow broadly the same criteria as determined by their regulators, the WIC in Scotland and Ofwat in England and Wales.

Shared commitments in addition to those addressed in Chapter 5.3.2 will be in customer service, keeping charges low, offering value for money and aspiring to be the best service provider not only in the water industry but in the utility sector (Scottish Water 2015c).

With regards to the climate in Scotland, the uptake of water butts and the disconnection approach may not be as successful in comparison to drainage utilities in the South of England encountering water scarcity issues and regularly implementing hosepipe bans.

10.4 CASE STUDY - DETAILED DRAINAGE MODELLING

Consultation with active detailed drainage modellers was undertaken in addition to researching the available literature from academics and practitioners with reference to industry wide guidelines and publications to understand the criteria involved prior to conducting the research experiment.

To achieve objective 3 and research aim 2, modelling scenarios were conducted running repeated scenarios iteratively reducing the surface water flows arriving at the combined sewer pumping station allowing volumetric and durations of pumping station operation, in a variety of situations, of removing surface water prior to entering the sewage pumping station to be obtained.

10.4.1 Methodologies

A number and variety of drainage modelling software packages were researched for suitability for use (Chapter 3.6). The typical wastewater network under investigation was initially reviewed utilising extracts taken from the geographical information system (GIS) supplied by the research author's sponsors and determined to possess the generic components of a combined sewer system which had the potential to be utilised as an exemplar site.

The utilisation of GIS was also adopted and promoted in the paper by Becker et al (2006) representing the stormwater management information system which identified the potential for realising surface water decentralisation methods in conjunction with identifying areas suitable for disconnection. The use of GIS tools also provided necessary information to understand the spatial distribution of the data contained as discussed by Schenk et al (2007).

However this particular focus on the utilisation of GIS software was not taken any further due to the context with which it was utilised, as was the approach adopted by the Hyder Consulting Ltd (2004) report (Scottish Government 2014c) as part of the Glasgow strategic drainage plan was disregarded as the site concerned wastewater being carried via open watercourses as opposed to a combined sewer system and significantly larger drainage catchments incorporating a number of differing variables to the selected wastewater catchment under investigation in this research.

The software package Mapinfo, a tool similar to GIS, primarily concerns above ground information and although also utilised in the Hyder Consulting Ltd (2004) report was not selected as this programme was not suited to address hydraulic flows and surcharging implications within sewer systems.

The MUSIC software as reported by Moore (2006), popular with drainage practitioners in Australia as reported by Bastien, Arthur and McLoughlin (2011), was not selected for use as this program albeit assisted with GIS and similar to this researches methodology is primarily utilised to aid in the identification of locations to retrofit SUDS to secure the maximum water quality benefit of the receiving watercourse.

The WINDES software also reported and utilised by Moore (2006), mainly used for small scale drainage designs was disregarded as the research investigation primary focus was on obtaining information on the volumes being receiving at and durations of operation of a singular pumping station.

The CITYDRAIN modelling concept as utilised by the integrated urban wastewater system modelling for strategic planning by Seyoum (2011), addressed the requirement for integrated urban wastewater system modelling however this approach was diagrammatic and would not provide the hydraulic investigation required to achieve the identified research aims.

The software package utilised in this research was the Infoworks Modelling program. This package, favoured amongst drainage utility practitioners in Scotland, allows the hydraulic performance of the sewer system(s) under investigation to be critically examined.

The hydraulic approach adopted in this research is supported with numerous examples of research into identifying rainfall runoff and flows within combined sewer systems such as reported in UKWIR 04/WW/17/4 and by Messmer, Schultze and Ogurek (2008). The decision to select and utilise this software package is supported as the same program used in the SNIFFER (UE3(05)UW5 (2006) investigation report.

By identifying and measuring the volume of road and roof drainage flows passed forward and the duration of the pumps operation, energy consumption and costs were determined. Over the 168 storm events investigated it identified that 90% of the volumes being passed forward by the pumping station was surface water flows. It was then determined that 57% of the surface water originated from the roads and 43% attributable to roof runoff. These percentages will vary with figures identified in other drainage modelling exercises due to differing locales possessing various levels of urbanisation and development.

The scenarios conducted utilising the three modelling criteria of 1 in 1 Year Storm Event, 1 in 30 Year Storm Event and over a Typical Year concerning 168 Storm Events were selected following discussion with drainage modelling consultants whose approach is supported by various reports by professional drainage modelling practitioners such as by Caledonian Water (2014), MWH (2014), JBA Consulting (2014) and Natural Scotland Scottish Executive (Speirs 2007).

The 60minute duration was utilised as the critical storm duration and supported by its utilisation in Hyder Consulting Ltd (2004) report into retrofitting SUDS.

However as with all software packages it should be noted that there are limitations in verifying hydraulic predictions due primarily to the lack of appropriate and fit for purpose survey data to fully recognise the sewer system conceptually in comparison to the physical characteristics in reality. The confidence level of the model was good however the model utilised was a skeletal model.

It is recommended a model review report be carried out to validate the confidence of the model, update through survey works as and where applicable and to improve the certainty of the data produced by any future modelling scenarios being utilised which provides the foundation for information when progressing to the detailed design for the implementation of any retrofit SUDS solution.

The role of uncertainty in the modelling results in addition to the limitations of the outputs and the models used in these investigations should also be considered particularly when utilising the data obtained for further examination. The data produced through the detailed drainage modelling exercises conducted in this research are utilised in the financial examination chapter. The monetary values involved in this research were relatively low in comparison to the savings potentially achievable when pumping significantly larger flows. The importance in the confidence rating of the results and data obtained will become more pertinent if used as evidence and justification in decision making processes.

In addition to the numerous drainage modelling exercises investigated, in order to appropriately and adequately determine volumes and flows within the combined sewer system which may be applicable for removal and attenuation, similarly the foundation and approaches addressed to select the SUDS retrofit scheme proposed requires to be examined and substantiated.

Retrofit SUDS

Determining suitable individual components for the retrofit SUDS scheme utilised information detailed by Stovin and Swans 2007 paper on Retrofit SUDS - Cost Estimates and Decision Support Tools.

The information available and delivered in a clear and concise manner was ideally suited to the requirements of this proportion of the research. This approach allowed a simplistic identification of the components possible and their applicable costs for construction.

From conducting an extensive review of the available literature there were other techniques and decision support tools accessible for drainage industry practitioners, developers, landowners, consultants, planners, engineers and architects.

Multi criteria design making (MCDM) techniques such as discussed by the SNIFFER (UE3(05)UW5 (2006) report which is defined as a series of methods for selecting a single SUDS option from many, based on a comparison of a number of criteria, usually considering economic, environmental and social considerations. In support of this technique Ellis et al (2006) identified a multi-criteria decision support framework for the selection of SUDS.

Similarly a SUDS option decision support tool has been put forward by Scholz (2006), which is aimed primarily at planners to assist in the identification of specific and appropriate SUDS solutions suited for the particular locality under review by considering economic, environmental and social factors. The tool was not utilised in the selection of the SUDS options in this research as it was deemed too simplistic for incorporation and unclear how to utilise the tool a view similarly supported by Stovin in 2007 (Scholz 2007).

The paper by Singh et al (2005), which endeavoured to use and build upon the approach put forward by Stovin and Swan (2007), emphasizing the requirement to improve the integration of drainage area planning with land use, planners, architects and engineers was positive however would not assist in identifying and prioritising disconnection opportunities as it took insufficient consideration of the hydraulic modelling impacts in the options selection process adopted in this research.

From the modelling approaches investigated, and a failing in this research, there were no packages which addressed the hydraulic capacity and condition of the road gulley's or the pathways routing surface water as reported and discussed by OFWAT (2011).

This period of data collection and methodologies addressed were vitally important as the information collected, collated and examined allowed research aim 2 to be achieved whilst providing substantial data for the financial examination chapter into the level of energy consumption to be investigated, calculated and determined.

10.5 CASE STUDY - FINANCIAL EXAMINATION

The modelling investigation conducted in this research allowed the financial implications of using such a technical tool and the substantial potential quantifiable and unquantifiable costs and benefits to be identified and determined where possible (Chapter 7). The financial examination on the electricity price was conducted utilising the price of electricity at that time (2010).

The financial data thus obtained allowed a direct comparison to be made of the savings achievable through reduced electricity costs from the detailed drainage modelling exercise against the expenditure necessary to implement a retrofit SUDS solution to remove the surface water flows from the combined sewer systems.

The research experiment was then expanded to investigate the financial implications of three sectors firstly conveying 315,360 megalitres to treatment at the national level considering 2,100SPS's and the cumulative impact, secondly the impact of the "Rain Tax" with a potential disconnection rebate scheme and thirdly comparisons with other utility providers.

10.5.1 Detailed Drainage Modelling

From the data obtained in the detailed drainage modelling research experiment a financial examination to determine the costs of electricity consumed at the SPS under the varying local level modelling and theoretical scenarios was conducted.

The monetary savings through a reduction in energy consumption at the minor level by removing all of the surface water flows at one SPS @ over a 25 year period was identified.

Discount rates are used to convert costs to present values to allow comparisons to be made. The costs were calculated using a uniform series present worth equation (Chapter 3.7.1) and a 3.5% discount rate. This rate was selected as it is the recommended discount rate to be utilised in the UK Governments Green Book (2011) Edition (DFPNI 2014), which was established to be useful for anyone conducting a basic evaluation of a project or programme.

The selection of this discount rate is supported by its similar adoption and utilisation in the paper by Bastien, Arthur and McLoughlin (2011), which addressed SUDS Retrofitting - options for improving runoff from industrial areas. Thereafter no further discount rates were investigated.

10.5.2 Cost For Retrofitting SUDS

Costs were calculated for retrofitting a variety of sustainable urban drainage techniques and alternative solutions in the case study catchment, with unit costs developed for the range of solutions proposed.

Construction, maintenance and whole life costs for the solutions potentially retrofitted into the case study location were determined by using a preliminary review of the potential options available, conducting a notional optioneering phase prior to detailed optioneering.

The desktop approach taken utilised whole life costing models, a construction cost handbook and a decision support tool. The WERF BMP and LID Cost model and the SUDS For Roads cost tool (Chapter 2.6.3) were utilised in the financial examination of the Raingardens, Swale and Basin due to their availability and user capability.

The fields present were comprehensive however the information obtained was regarded as being at the high level due to the number of exclusions. There were no corresponding data sheets available to cost the associated pipework and a construction cost handbook was used.

The CESMM3 Carbon and Price Book (2011), was utilised although there are other construction cost handbooks available such as Spon's First Stage Estimating Handbook (Spain 2010). Either of these construction handbooks could have been used, albeit time consuming and requiring a significant amount of user knowledge of the subject matter.

The methodology behind the selection process and the financial examination thereafter utilising these costing models of the retrofit costs itemised do not take into account value added tax, nor other fundamental site specific costs such as those incorporating land prices (Duffy et al 2008), consultants design and contractors costs, product replacement, profit margins and risk profiles or those relating to soil type.

This approach is similarly acknowledged, adopted and described by Stovin and Swan (2007) report into retrofit SUDS – cost estimates and decision support tools, Atkins (2004), SUDS Retrofit Research Project for Scottish Water and the Environment Agency Science Report SC060024- using science to create a better place into cost benefit of SUDS retrofit in urban areas (2007).

The scale of difference between the costs saved in grid electricity at the individual SPS under investigation compared to the costs for a retrofit programme as determined by these tools are considerable. This finding relates directly to the assertion in Chapter 2.3, that the transition may incur upfront costs which at the outset will provide very little return however will produce increasing financial, environmental and social benefits.

The decision support tool selected has been produced by UKWIR to specifically address the potential solutions for reducing surface water flow from the combined sewer system highlighting positive and negative impacts on stakeholders.

By utilising the decision support tool, the total cost benefit of these retrofit solutions was determined to be minus £101,298 with a saving of 12tonnes CO_2e per year.

The disparity between the two costs reduces when viewed in parallel alongside the potentially substantial saving in greenhouse gas emissions (CO_2e) per year.

There is a counterbalance to the costs for retrofitting these selected SUDS in the environmental and social benefits they bring (Chapter 2.6). The introduction of rain-gardens to properties across the drainage catchment and the installation of a basin adjacent to the SPS will assist in providing the multiple benefits of green infrastructure identified in Chapter 2.4.6.

Green infrastructure refers to the 'green' and 'blue' features that exist within the natural and built environment whereby the soil, vegetation and natural processes manages surface water runoff creating improved natural habitats for all. Previously recognised as open spaces and used only for sports and recreational purposes or for their aesthetical appeal the term green infrastructure now reflects an alternative view.

Green spaces are now seen as providing a number of functions delivering multiple benefits such as reducing flooding risk, improving habitats for wildlife whilst improving psychological health and wellbeing (Chapter 2.6.2).

Installing raingarden's will improve water quality, biodiversity and assist in flood protection whilst increasing resilience to the impacts of climate change (Lundy et al 2012). An advantage of establishing raingarden's throughout the catchment is that they can be sized to fit anywhere (Barratt 2013).

Constructing basins are more challenging from a design aspect due to their size and implications of land take however there implementation will also provide a number of multiple benefits (Bastien et al 2011), (Apostolaki et al 2009).

These numerous benefits many similar to those achieved with raingarden's include improvements to the habitat providing urban diffuse pollution mitigation through pollutant removal and opportunities for amenity recreation and education (Wade and Garcia-Haba 2013)

Bringing nature back into urban environments through the construction and with effective maintenance of these retrofit suds will assist in achieving many of the drainage utilities identified financial, environmental and social improvement drivers (Chapter 5.3.2).

10.5.3 Cumulative Impact At The Local Level inc Macdonald Road

The scenario investigated concerned a number of SPS's operating in sequence, as is the case in Edinburgh, the capital of Scotland. From the investigation into the financial implications of consecutive sequential pumping, it was shown that a significant financial saving was achievable.

The results showed that from an annual approximate cost, operating the SPS's in sequence, the grid electricity consumption is £10k which could potentially be reduced to £1k.

This financial saving when examined over the same 25year period as previously investigated would result in a net present value saving of over £130,000 through grid electricity costs alone. The actual figures will be higher as the pumping stations at this location increase in size towards the treatment works and thus incur greater costs realising greater savings.

The identification of a significantly larger SPS at McDonald Road conveying considerably higher volumes and operational durations magnifies the significance of the financial implications of reducing electricity consumption at the macro level concerning 2,500SPS, a view particularly pertinent when transporting 315,360 megalitres annually to treatment across the drainage utilities jurisdiction.

The expenditure involved will be in the millions of pounds from the CAPEX and OPEX needed to implement specific retrofit SUDS attracting attention, encouraging discussion and debate thereby providing further information to support the advancement of knowledge to the key stakeholders and actors on the justification to remove surface water from combined sewer systems.

10.5.4 Disconnection Rebate Scheme And The "Rain Tax"

With the discovery during the literature review of other UK drainage utilities providing surface water disconnection rebate schemes to households promoted by the recommendations in the Pitt Review report (2008), a financial examination on the information available and implications of implementing a similar scheme for the City of Edinburgh Council was undertaken.

The available information on the breakdown of wastewater services provided in the City of Edinburgh Councils (2013) bill is limited. However the principles behind the improvement drivers of why disconnection rebate schemes are necessary and the substantial findings obtained and described in the financial examination are both comparable and justified by numerous drainage utility organisations currently operating similar disconnection rebate schemes for their respective household customers.

The improvement driver for the transition of UK drainage utilities practices as recommended in the Pitt Review (2008), was the extreme flooding incidents in 2007. Other drainage utilities also possess improvement drivers such as reducing CO2 e and deliver clear information to the benefits achievable and the barriers to success in bringing about decisions to institute changes in policy and procedures and ultimately transition.

The improvement driver for the drainage utility in Georgia, USA, as reported by the Georgia Conservancy (2007) was a lawsuit, which required the organisation to identify and control both point and nonpoint sources of pollution whilst the drainage utility in Minneapolis City of Lakes, USA in 2013 reported the improvement driver for transition was water quality, amenity and recreational use.

In both cases, clear information is currently provided to the drainage utilities household customers such as in Minneapolis's stormwater quality credit application form and which provides an uncomplicated checklist for disconnection. This clear information provides three key stages to enable the customer to conduct straightforward calculations to achieve a percentage reduction in their properties stormwater utility fee.

Firstly the customer is advised to provide what percentage of their property of impervious area is treated for quality secondly this figured is multiplied by 50% (Max Credit) which thirdly equals the percentage reduction/credit in their properties stormwater utility fee.

These disconnection rebate schemes provide substantial weight in supporting the research's assertion that a 50% discount rate for households connected to the combined sewer system is practical, possible and viable.

The findings from DEFRA's (2007) report into the funding and charging arrangements for SUDS supports the research's overarching goal by relating to the validity and availability of utilising SUDS as a viable and sustainable alternative to current urban drainage solutions. The understanding in 2007 (DEFRA 2007), was that existing drainage arrangements provide insufficient incentives to attenuate surface water flows even in circumstances where measures would be economically attractive. Advising that either through lump sum subsidies, discounts to on-going charges or through a tradable organisation, disconnection and retrofitting SUDS should be positively encouraged for existing housing stock connected to the combined sewer system.

Comparisons of similar incentives have been discussed in this research in regards the issues, challenges and the barriers to success faced by other utility providers.

10.5.5 Similarities With Other Utility Providers

Other utility service providers were investigated to identify similar challenges and mechanisms which they have adopted to assist in the environmental agenda such as the 8% green levy required by the UK government in the OFGEM report (2013), to be included and clearly identified in their consumer bills allowing comparisons and contrasts to be examined and completed.

The outcome of this assessment of alternative approaches to incentive design provides a direct correlation between the drainage utility used in Chapter 5 and the challenges faced by other UK utility service providers (Earwaker and Hannah 2011).

The consequence of the research's key findings is that the cost of grid electricity can increase as well and decrease due to a multitude of factors, political, social, environmental and economic amongst others and thus warrants revisiting and updating to recognise not only the current price but also the currently available and political appetite for environmental improvement schemes.

The transitioning approach adopted in this research's methodology requires to be tested on and by the key stakeholders identified for suitability and determination of its level of success.

10.6 TESTING OF THE TRANSITIONING APPROACH

Following the presentation of the findings from this research (Chapter 4 to 9) questionnaires were provided to participants for completion to obtain, evaluate and learn from information on key stakeholders opinions and views in order to test the level of success of the transitioning approach adopted and put forward by this research.

10.6.1 Stakeholder Collaboration And Engagement

As discussed in Chapter 9, workshops and meetings are required to be co-ordinated, convened and chaired with presentations delivered to the identified, targeted and assembled key stakeholders on the research aims and objectives.

Positive comparisons on this research are apparent in the fundamentals of stakeholder collaboration and engagement as described in the Wright et al (2011) paper, which conducted an extensive consultation exercise into stakeholder perceptions on quantifying and the financial implications of urbanisation.

This approach was also utilised to effectively communicate and successfully obtain information from attendees by Cashman (2008).

10.6.2 Quantitative Methodology

Similarly the research's selected quantitative methodology is supported through the assessment of the social impacts of SUDS in the UK study conducted by Apostolaki (2009), (Susdrain 2015b). In addition the same approach to this research by conducting workshops delivering presentations encouraging discourse and obtaining attendees views and opinions through the use of questionnaires were utilised in the transitioning process to disconnect surface water flows from households by the drainage utility of the City of Ann Arbor (2007).

The results obtained from wastewater industry professionals identified an overall agreement with the research aim's and objective's supporting the justification of reducing surface water flows prior to pumping using a transitioning approach.

However a view put forward and shared in this research, following investigation into the Swiss water management sector as reported by Lienart, Monstadt and Truffer (2006), and Boller (2003), identified that professional's require support and resources to manage and overcome existing issues and challenges whilst academics frequently query the long term vision and sustainability aspirations.

10.6.3 Transitioning

A key feature of this and any successful transitioning approach, as demonstrated in the large number of transitioning examples previously described, is to identify responsible parties and engage the community.

In conjunction with the key stakeholders identified and contacted there are also Actors to be recognised who are involved in the transitioning process such as from the academic community, local council authorities, landowners, residents, frontrunners and champions similarly report by Brown, Farelly and Loorbach (2013), businesses and community groups as determined by SWITCH Urban Water (2013), amongst others who can influence decisions and decision makers.

A key requirement of any successful transitioning process is an effective communication strategy such as consultations conducted by Natural Scotland, Scottish Executive (Speirs 2007). The vision must be clear and concise and importantly examples of successful transitions need to be provided to all key stakeholders.

In this research several successful transitioning projects involving the disconnection of surface water flows were identified and documented.

This forward thinking approach is supported by the results obtained in the SUDS and Sustainability paper by Heal, Mclean and D'Arcy (2004), which reported the incentive to utilise SUDS is more likely to be successful if financial benefits can also be realised.

The future for this research arena is very positive with several participants requesting the research author investigate other case study areas which involve the pumping of combined flows up into the wastewater treatment works in particular as potential sites to achieve greater results which links directly to the next round of transitioning stage (Chapter 8.4), as part of the transitioning approach used.

However many of the attendees at the research presentations queried the definition and measurement of the term, success (Chapter 9.4.5).

10.6.4 Stakeholders And Actors

The transitioning approach adopted, identified multiple stakeholders as designated by the Scottish Government. However due to time constraints and practicalities of arranging, co-ordinating and conducting effective workshops, providing meaningful presentations and obtaining feedback through questionnaires, was limited to the key drainage utility personnel only.

The success or failure of this transitioning approach can be challenging to measure in respect of the definition of success. From those personnel engaged positive feedback and comments about the research aims and findings were received. To fully understand the effectiveness of the transitioning approach, the research requires to be presented to a greater audience and ultimately involve all of the key stakeholders identified.

The barriers and individual drivers for the implementation of a retrofit SUDS programme will be different for each stakeholder involved a point which is also supported in Bastien, Arthur and McLoughlin (2012) paper.

It is also important to recognise each Actor involved will possess a variety of both similar and differing drivers and are likely to be affected by a proposed project either positively or negatively a theme supported by Niemcyznowicz (1999).

The social aspects of SUDS were highlighted in a report by Heal, Mclean and D’Arcy (2004), which discussed conducting door to door survey's, a methodology similarly conducted in the report by SNIFFER (UE3(05)UW5) (2006) also identified that householders and residents were more concerned with road traffic in comparison to open water bodies.

Actors will influence the key stakeholders through three primary routes, namely developing the message, delivering the message and reinforcing the message an interpretation supported by Lencd (2013).

10.6.5 Influence

To be an effective influencer and a failing in this research due to research scope and time limitations is that the opportunities need to be presented to the wider organisation; other organisation’s (Chapter 5.2) and not just within specific departments or divisions and to include the wide variety of actors potential impacted.

Similarly the overall benefit to the organisation of taking such a transitioning step and focusing on the bigger picture not just in specific objectives needs to be demonstrated.

With the research goal incorporating a variety of research aims and objectives being presented, discussed and deliberated upon, a period of reflection is required for evaluation and learning to occur in order to review and understand the reasons and complexities behind the successes or failures of the activities designated within the transition agenda and learn from them, an assessment supported by Geels (2005).

It is important to recognise that as situations and circumstances change over time as described by Jones and Evans paper in (2006), which addresses the historical progress of drainage practices and through ever evolving social and political pressures, the transition process may now be moving towards or further away from the originally identified vision as discussed by Keath and Brown (2008).

It is therefore vital to recognise that politics and power are intrinsically linked (Chapter 5.2) to any transitioning process and a significant shift in both is often required to bring about effective change as reported by Woodhill and van Vugt (2010).

10.7 SUMMARY

This chapter discusses and critically evaluates the key activities carried out during this research. The available literature and methodologies behind the selection process are examined in detail to provide justification for each of the three key stages conducted;

- Determination of a Suitable Transitioning Approach
- Case Study: Drainage Utility, Detailed Drainage Modelling and Financial Examination
- Testing of the Transitioning Approach

The critical evaluation has established a successful transitioning framework which achieves the overarching goal of this research by using innovative integrated urban water management techniques and providing an understanding of how efficient utilisation of wastewater assets and infrastructure can transition from the existing paradigm of managing wastewater infrastructure to a sustainable paradigm.

CHAPTER 11 CONCLUSION

This chapter presents the conclusions of the research aims and objectives advancing the knowledge that the removal of surface water from the combined sewer system is justified by utilising a transitioning approach.

11.1 INTRODUCTION

The overarching goal of the research is to establish a successful forum to transition from the existing paradigm of managing wastewater infrastructure to one that achieves a more efficient utilisation of wastewater assets and infrastructure.

Scottish Water, the drainage utility is the single largest user of power in Scotland (2011) and faced with two challenges, firstly how to reduce current energy consumption levels and secondly to mitigate against increases in energy costs.

Presently, wastewater treatment works in Scotland receive 315,360 megalitres of combined sewer flows annually. The vision for sustainable cities of the future is to have a separate system of foul and surface water sewers and infrastructure and it is through transitioning frameworks which can achieve the step changes required to move from one paradigm to another.

The research aims and objectives described at the outset in Chapter 1.3 have been achieved. With the detailed information obtained in this research, the removal of surface water from combined sewer systems is justified through the identification, determination and utilisation and testing of an effective transitioning approach.

The main research contribution is the development of a transitioning framework approach (Chapter 4.1).

The attendees at the workshops and presentations agreed (Chapter 9.4.6) that the removal of surface water from a typical combined sewer system is justified by applying a transitioning approach and focusing on the energy consumption required to pump increased volumes during storm events (Chapter 4.1).

The responses to (Question 17 and 18) are significant. Despite the attendees previous confirmation that finance was their most influential consideration (Question 12), and when presented with a weak economic case they agreed with the research hypothesis (Chapter 1.3). The key finding of the research is that the transitioning framework approach developed was successful. The determination of the level of success was discussed in (Chapter 9.2).

11.2 AIM 1, OBJECTIVE 1 - DETERMINATION OF A SUITABLE TRANSITIONING APPROACH

The research has completed objective 1 of research aim 1 by investigating and determining a transitioning approach of how efficient utilisation of wastewater assets and infrastructure can be achieved.

The novel transition framework approach developed (Chapter 4.1) incorporates and improves on the key research in the field including steps and tasks identified in Table 1, (Kotter and Rathgeber 2006), (Chapter 2.2), transitioning approaches such as the information provided in the Urban Water Management Transition Framework as reported by Wong and Brown (2009) (Chapter 10.2.1) and the SWITCH transitioning management cycle by SWITCH Urban Water (2013), (Chapter 3.3.2).

The novel transition framework approach developed produced a methodology under the transition stages of arena, agenda, case study and monitoring which clearly identifies and outlines the necessary steps to establish and define the issues.

It identified all of the relevant parties allowing the communication of research and findings to be delivered in an effective environment to bring about the dialogue necessary to influence the decision makers and ultimately accomplish a change in direction or focus towards achieving the identified vision as supported by the SWITCH transitioning management cycle, SWITCH Urban Water (2013).

This research is novel as it is the first to look at providing justification for the reduction of surface water flows in combined sewer systems by specifically conducting three key tasks (Chapter 4.4). Firstly, developing a suitable transitioning framework, secondly, investigating through detailed drainage modelling and financial examination the potential for savings in grid electricity at sewage pumping stations and thirdly, convening workshops, meetings delivering presentations obtaining evidence from attendees to test the success of the transitioning approach determined and adopted.

Essential to any successful transitioning process from the historical conveyance and "same old same old" approach is the effective dissemination of transitioning examples including green roof infrastructure, surface water removal/attenuation and disconnection projects and programmes, in addition to addressing examples of the installation and implementation of innovative technologies in other sectors such as renewable energy generation.

Each stakeholder will face differing challenges and priorities however they will all share the fundamental principle that there will be an improvement driver behind any transitioning process.

Furthermore, many of the improvement drivers and the potential benefits achieved will be financial which can be quantifiable and economic values applied, however there are considerable intangible benefits which are challenging to quantify and monetise.

By organising, engaging, presenting and encouraging discourse with the key personnel within the Scottish Government's identified stakeholders the feedback from these representatives should be recorded, collated, assessed and deliberated upon to further advance the knowledge put forward by this transitioning approach and contributing to key research in the field.

There are academic impacts to this research. The research has demonstrated pumping significant volumes of surface water considerable distances is an inefficient use of resources. The research has determined that a transition to the future vision of a more optimum utilisation of wastewater assets and infrastructure is achievable with a suitable transitioning approach when addressed at the macro level, coupled with advances in knowledge and understanding of the following features in Table 31.

Table 31. Components Investigated In Determining The Successful Transitioning Approach

Transitioning Approaches	Stakeholders and Actors	Communication Strategies	Green Infrastructure
Intangible Benefits - Natural Capital	Energy Costs - Current and Future	Disconnection Rebate Schemes	Investment, CAPEX and OPEX
Environmental Awareness and Education	Quantitative and Qualitative Methodologies	Sustainable Urban Drainage Systems (SUDS)	Separating Surface Water From Combined Sewer Systems
Computer Software, Hydraulic Modelling and Analysis of Wastewater Networks		Improvement Drivers - Increased Urbanisation, Impact of Climate Change	
Legislation, New Policies and Stricter Controls, Higher Penalties		Innovation in Surface Water Treatment Practices and Runoff Strategies	

This research in developing the transitioning framework approach investigated numerous practical and academic components. Practical examples implementing surface water management plans and techniques are identified (Chapter 2.4.1 and Chapter 2.4.4), discussing the improvement drivers and barriers to success (Chapter 2.2).

Academic involvement and impact is apparent throughout the research methodology (Chapter 3.2) and developed transitioning framework approach. Included in the strategic and tactical levels, academics are to be engaged in the Develop the Transition Arena and Monitoring stages (Chapter 4.2 and Chapter 8). In the case study detailed drainage modelling stage (Chapter 6) available academic literature was reviewed.

One of the main research contributions which highlight's the academic impact of this research is its applicability for utilisation by other research projects focussed upon achieving transition. The transitioning framework approach has been developed as a cycle (Fig 11) to continue advancing knowledge. For any location and circumstance the developed transitioning framework approach stages can be adopted and utilised. The stages within the transitioning framework are fixed (arena, agenda, case study and monitoring) however the activities contained therein (Chapter 4.1) are flexible and can be enhanced or reduced to suit. The specific details, subject matter and scope of work within the Case Study stage will be pertinent to the new research topic (Chapter 9.5.7). As long as the information obtained is fed back through the Monitoring stage this will continue the cycle and direct the next transition arena and agenda advancing knowledge and contribute further to key research in the field.

The findings possess a wide scope for exportability to other departments within the drainage utility under investigation, different drainage utilities, other utilities and organisations. The research scope, hypothesis and conclusions will assist academics, stakeholders and drainage practitioners by providing supporting and justifiable evidence to promote the removal and reduction of surface water volumes in the combined sewer system in future research projects Chapter 11.6).

11.3 AIM 1, OBJECTIVE 2 - TESTING OF THE TRANSITIONING APPROACH

The research has completed objective 2 of research aim 1 by testing the transitioning approach through a series of convened workshops, presentations and meetings with participants completing a questionnaire establishing that the approach would be successful.

The participants engaged agreed a transition in thinking was required regarding the utilisation of wastewater assets and infrastructure accepting the transitioning approach put forward an appropriate way to initiate the transition.

From the questionnaires completed the respondents unanimously agreed that surface water flows should be removed as well as reduced from the combined sewer system. The conclusion drawn that the respondents selected a total removal of surface water from the system at the local level is significant based upon the economic evidence and information provided. This finding provides further justification that the novel transitioning approach developed in this research has been successful.

The majority of respondents stated they would also be supportive of a disconnection rebate scheme as recommended in the Pitt Review (2008) and currently being implemented by other UK drainage utility companies.

The results obtained from wastewater industry professionals demonstrated an agreement with the research aim's and objective's supporting the justification of removing surface water flows prior to pumping by using a transitioning approach.

The fundamental question of the novel approach taken in this research and seen as the advancement of knowledge, can the removal of surface water flows from combined sewer systems be justified by applying a transitioning framework approach and focusing on grid electricity consumption levels was supported by the respondents.

This respondent's position was strengthened and wholly endorsed when combined with the other financial, environmental and social benefits which could be achievable.

The methodology and key findings of the research can be reviewed, dissected, amended and utilised as foundation stages to progress further investigation and research to advance knowledge in this arena to ultimately achieve a transitioning towards a more efficient and sustainable utilisation of wastewater assets and infrastructure.

11.4 AIM 2, OBJECTIVE 3 - CASE STUDY - DETAILED DRAINAGE MODELLING

The research has completed objective 3 and research aim 2 improving the understanding of the implications of removing/attenuating surface water from the combined sewer system by obtaining data through computer modelling.

An Infoworks computer modelling software package was used to conduct repeated scenarios iteratively reducing the surface water flows arriving at a combined sewer pumping station.

The proportion of surface water was determined to be 57% from Roads and 43% from Roofs.

The 1 in 30 year storm event scenario utilised by detailed drainage practitioners, (JBA Consulting 2014), recommended for use (Sanderson 2010) and (Hurford et al 2012) determined that volumes would be reduced from 257m³ to 23m³ with all of the surface water flows removed.

These volumes require the SPS to operate from 4.7hours to convey the storm flows as opposed to 0.43hours under dry weather operating conditions. This is a reduction of 234m³, 4.57hours which equates to 91% of flows being unnecessarily transported to treatment.

Cumulative impacts of a theoretical scenario concerning a number of pumping stations operating in sequence determined even significantly larger volumetric reductions and durations of SPS operation can be achieved.

The pumping regime under investigation was 15l/sec and is considered minor when compared to other pumping stations regimes currently operated by the drainage utility such as at McDonald Road SPS, which is 4,500l/sec and in continuous operation.

Similarly the financial, social and environmental benefits achieved through the removal of surface water entering the combined sewer system will be substantial and increasing depending upon the scale of the receiving flows and where pumping stations are required to operate in sequence.

11.5 AIM 3, OBJECTIVE 4, 5 and 6 - CASE STUDY - FINANCIAL EXAMINATION

The research has completed objective 4, 5 and 6 and achieved research aim 3 through the identification and assessment of the financial implications of removing/attenuating surface water from the combined sewer system.

The drainage utility is the single largest user of power approx. £40 million per annum in Scotland (2011). There is a corporate commitment and social responsibility on the utility operating 2,100 SPS's and treating 315,360 megalitres of combined sewer flows annually, to reduce energy consumption and mitigate the impacts of climate change (Chapter 2.3). Greenhouse gas emissions from wastewater treatment and network processes accounted for 40% of the annual grid electricity bill in 2010/11 (Fig 3).

From the research experiment the monetary savings through a reduction in grid electricity consumption achievable at the minor level by removing all of the surface water flows at one SPS @ over a 25 year period was £4,368 and deemed to be insignificant in comparison to the potential upfront costs of over several hundred thousand pounds (Chapter 7.3.3) for a full retrofit SUDS scheme.

The financial examination conducted has been unable to identify sufficient quantifiable financial savings, through the reduction in energy consumption by removing surface water from the catchment draining to the individual SPS to justify the cost of implementing retrofit SUDS scheme on its own to be a viable option thereby negating any action within the current operational practices and activities of the drainage utility.

However the removal of surface water from the combined sewer system as identified through detailed drainage modelling and subsequent financial examination using whole life cost models, construction cost handbook and a decision support tool, provides a net saving of 12 tonnes of CO2e per year achieving an alternative improvement driver.

The retrofitting of a separate surface water sewer can also be seen as installing additional pipework, however will be utilised as part of a raft of measures ultimately reducing the surface water flow content (Chapter 2.4.2).

The financial implications of consecutive pumping addressing 8SPS operating in sequence demonstrated an annual approx. cost of £10,000 could be reduced to slightly over £1,000 which over the same 25year period would result in a net present value saving of over £130,000 through energy costs alone.

When addressed at the macro level i.e., with over 2,100 pumping stations, some operating in sequence the stature of the multiple quantifiable improvement drivers and intangible benefits achievable becomes amplified, the figures involved more significant and powerful in the justification for such a transition in thinking for a drainage utility treating 315,360 megalitres of combined sewer flows annually.

The investigation determined that by promoting a disconnection rebate scheme within the catchment area to encourage householders to divert their roof drainage from entering the sewer system, a reduction of up to 43% in surface water flows requiring pumping during the storm events will be achieved producing significant savings in the drainage utilities greenhouse gas emissions (CO2e) per year.

Improvement drivers as identified will be partially and completely achieved with zero upfront capital cost with zero on-going operational or maintenance costs to the drainage utility.

A key finding of the research is the surface water disconnection rebate for the drainage utilities household consumers of approx. £50 per household and two million households equates to an achievable annual saving for household consumers in the region of £100million.

Despite the drainage utility incurring a reduction in revenue from consumers, this will be offset by the significant increase in green credentials promoting innovative thinking and improvements in customer focus and engagement. In addition the drainage utility can become a main supplier and retailer for the water butts and similar type products thereby generating revenue.

Incorporating the UK Government's levy of 8% on energy utilities (Ofgem 2013), for environmental and social improvements into the drainage utilities bills for consumers coupled with the disconnection rebate scheme would generate considerable revenues, producing significant reductions in surface water flows realising many of the improvement drivers and intangible benefits discussed can be seen as a transitioning step to the new paradigm and sufficient to warrant further investigation.

The costs determined and described herein can be monetised and quantified however these also face uncertain futures such as through inflation, new emerging and innovative technologies, policy and procedures, legislation, climate change, land-values including maintenance and replacement costs amongst others and whose fundamental principles are supported by the multiple authoritative and academic reports presented.

11.6 FUTURE

For the next round of transitioning (Chapter 8.4) much of the information with regards to stakeholders, and actors have already been identified and it is up to the continuing participants driving the next cycle to recognise the stages of the determined transitioning approach (Fig 11) and understand that it is indeed a cycle in that it is constantly moving and evolving.

There are limitations to the research conducted. The transitioning framework developed in this research contained an Organise and Facilitate Stakeholders activity (Chapter 4.2.2), which could have been made more significant. This activity was limited however by research scope, practical logistics and time resulting in fewer and reduced workshops, agendas, formats and presentations being provided. The monitoring stage which condensed a number of the SWITCH activities (Chapter 3.3.2), was not selected for detailed analysis in the Case Study phase due to limitations of the research scope and time.

Computer modelling software packages which are utilised to conduct detailed drainage modelling scenarios will possess varying confidence levels and limitations (Chapter 3.5). Instabilities and assumptions due to the lack of fit for purpose and appropriate survey data are valid considerations in detailed drainage modelling scenario activities.

The models condition and level of performance will determine the reliability of results (Chapter 10.4.1). In addition to the limitations of the outputs and the model used in this research, the role of uncertainty in the modelling results should also be considered particularly when utilising the data obtained for further examination.

The financial implications of the potential intangible benefits were not examined in detail due to limitations of the research scope and timeframes.

The CIRIA 3045 BeST (Benefits of SuDS) user tool and guidance documents were not utilised in this research. This series of publications 3045a, 3045b, 3045c and 3045d supports practitioners estimate the impacts that drainage schemes can create. Understanding and communicating the benefits both informs and influences the key stakeholders and actors. Not progressed due to date of publication and time limitations of the research scope.

Tools such as Multi Criteria Analysis (MCA), a technique utilised to express data in units other than monetary values and bring into the appraisal process were also not used (Chapter 2.6.3) due to limitations of research scope and time.

Testing of the transition framework developed contained limitations (Chapter 9.3). Of the five key stakeholder organisations identified (Chapter 5.2), only the drainage utility was proactively targeted. The practicalities of arranging and conducting effective workshops, providing presentations and obtaining feedback through questionnaires meant that the responses were limited by its small sample size.

When collecting data it is often the case that it is not practicable to engage with all of the identified parties. As the data was obtained from the drainage utility personnel only (Chapter 10.6.4) this is seen as a significant limitation in this research (Chapter 11.3).

Advancements on the research conducted and discussed in Chapter 10 could be:

- The analysis will take different future energy cost scenarios and investigate the likely energy cost tipping point.
- Determine the annual electricity costs for the drainage utility to transport and treat surface water and the savings hypothetically achievable.
- The optimum number of pumping stations operating in sequence which will produce significant saving's to interest key stakeholders and make investment worthwhile.
- With ageing infrastructure, when is the optimum moment to change the pumps to operate more efficiently at the reduced foul flow only flow rates.
- The parallels of the transitioning approach implemented by the UK government to require energy companies to incorporate a percentage of the householder's bill to include Environmental and Social improvement schemes.

11.7 CONCLUDING REMARKS

The overarching goal of this research, to establish a successful forum to transition from the existing paradigm of managing wastewater infrastructure to a more sustainable paradigm that achieves a more efficient utilisation of wastewater assets and infrastructure has been accomplished. The findings from the research conducted exemplify an inefficient utilisation of wastewater assets and infrastructure.

The research hypothesis has been proved. The removal of surface water from a typical combined sewer system is justified by applying the transitioning approach developed and focusing on the electricity consumption required to pump increased volumes during storm events at a single SPS.

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Appendices

APPENDIX 1

12th ICUD Conference Paper

Removal of surface water from combined sewers applying the SWITCH Transitioning approach

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ABSTRACT

Scottish Water is the single largest user of power in Scotland. The water utility faces two energy challenges, firstly how to reduce current consumption levels and secondly the likely consequences of increasing energy prices over time. Unfortunately the benefits to be gained by making an investment which results in reduced energy consumption are often financially much less than the costs of achieving that change.

One current paradigm for addressing this energy problem is the transitioning approach recently articulated in the European Union FP6 project SWITCH. With existing techniques it is not possible to move towards a 'new world' in which the infrastructure will be different and have a much lower energy cost of operation. The transformation to a lower energy future will require up-front financial expenditure which, at the outset, will provide little return yet, once accumulated, will deliver increasing financial, social and environmental benefits.

This paper reports on a study investigating the removal of surface water from a typical combined sewer system in Scotland. The power costs for operating the Sewage Pumping Station, (SPS) in 2010, it's future operation in 2035 and the cumulative savings achieved through the removal of surface water were all evaluated and compared against the cost to retrofit an appropriate sustainable urban drainage system, (SUDS). (210)

KEYWORDS

Combined Sewer, Costs, Modelling, Scottish Water, SUDS, Surface Water.

INTRODUCTION

Scottish Water is the single largest user of power in Scotland and, as with any water utility, has considerable interest in examining ways in which energy used in operating assets and the impact on climate change can be reduced. The energy used in treating and pumping water and wastewater is of long term concern due to the likely increase of energy over time. One current paradigm for addressing this energy problem is that of transitioning which has recently been articulated in the European Union FP6 project SWITCH (Jefferies and Duffy, 2011).

The principle of transitioning is that it is not possible to move towards a 'new world' whereby the infrastructure will be different and have a much lower energy cost of operation with existing techniques. The change required will incur costs which, at the outset, have very little return yet once accumulated will produce increasing financial, social and environmental benefits (UKWIR, 2010). In addition to the construction of new infrastructure the change will involve a wide range of stakeholders such as environmental organisations and residents associations (Hottenroth, 2008). It is an example of a wicked problem in the words of sociologists and change managers.

The question arises how the change might be directed to make it both achievable and affordable (Payne, 2009). It is not possible to make a sudden step, or leapfrog, into the new state since the existing system must operate until such time as new infrastructure and procedures are constructed and implemented and the older, expensive system is no longer needed (Guangtao et al, 2008).

Typical wastewater networks receive large amounts of surface water during rainfall. This excess flow has considerable significance on combined sewers, sewage pumping stations (SPS) and wastewater treatment works (WwTW). Typical system constraints are; reduced carrying capacity, surcharging, and flooding incidents both external and internal (WRc, 2009). A transition in thinking is needed to retrofit systems to remove surface water and reduce operating costs. Unfortunately many of the works required are above ground (Conlan et al 2009) and will frequently have major impacts on communities and the fabric of cities.

This paper reports on findings obtained from an initial study investigating the removal of surface water from a combined sewer system whilst retrofitting sustainable urban drainage systems, (SUDS) (Stovin et al, 2007). A typical small drainage network in Scotland containing combined sewers, an pumping station and a treatment works was selected for this application. The study examined the progressive system change and the consequential variation in costs and benefits which might make the transition to the new paradigm possible. This paper represents the findings of extrapolating this data to reflect the impact of surface water removal on a system possessing one or more pumping stations in sequence, culminating in a network of 8 SPS.

METHODS

Modelling

The study location was the village of Collin in South West Scotland. The areas contributing surface water flows to the combined sewer network were identified, as were the areas that had the potential to discharge to an alternative location. In the model roads, roofs and permeable areas & driveways are all treated separately. Initially all three types of area were grouped together. Modeling used Info-Works CS which is a commercially available package used ‘off the shelf’ for this application.

Two different storm events were used;

- Event A – 1 in 1 Year Storm Event over a 60 minute Duration
- Event B – 1 in 30 Year Storm Event over a 60 minute Duration

For each event the following tasks were undertaken, the outputs from each modeling scenario being the flow rate and volume arriving at the pumping station;

- Identify the baseline flow and volumes of surface water discharging into the designated zones.
- Remove surface water flows from Zone A and re-run the model
- Remove surface water flows from Zone B and re-run the model
- Repeat the process for the number of zones designated

To assess the annual rainfall profile a typical year dataset was used to investigate the impact of 168 storm events over a year. In this case the outputs were flow rates and volumes pumped at the wastewater pumping station.

Financial

The wastewater pumping station used as the basis of the investigations possesses two pumps operating on a duty/standby arrangement. The motor rating for the pumps installed is 9KW. The current price for electricity negotiated by Scottish Water means the pumping station operates at £0.78KWH (€0.91KWH). In many locations there are a number of pumping stations operating in sequence pumping surface water from one area to another prior to receiving treatment. In some locations such surface water must pass through eight consecutive pumping stations – clearly wasteful in both money and energy.

Retrofitting SUDS

The areas of surface water removal had been identified through the modelling process. The next step was to identify and select the appropriate SUDS to suit using the SUDS Treatment Train Approach. A number of strategies were employed (SNIFFER, 2006), namely the: disconnection of roof drainage through the installation of water butts and reuse, swales and infiltration trenches, surface water sewers culminating in a pond prior to discharge to the nearby watercourse.

RESULTS and DISCUSSION

The modeling exercise identified four distinct zones in the South Collin catchment. These zones (Figure 1) had the potential for removal of surface water thereby reducing the overall flows entering the SPS and the operational and maintenance costs.

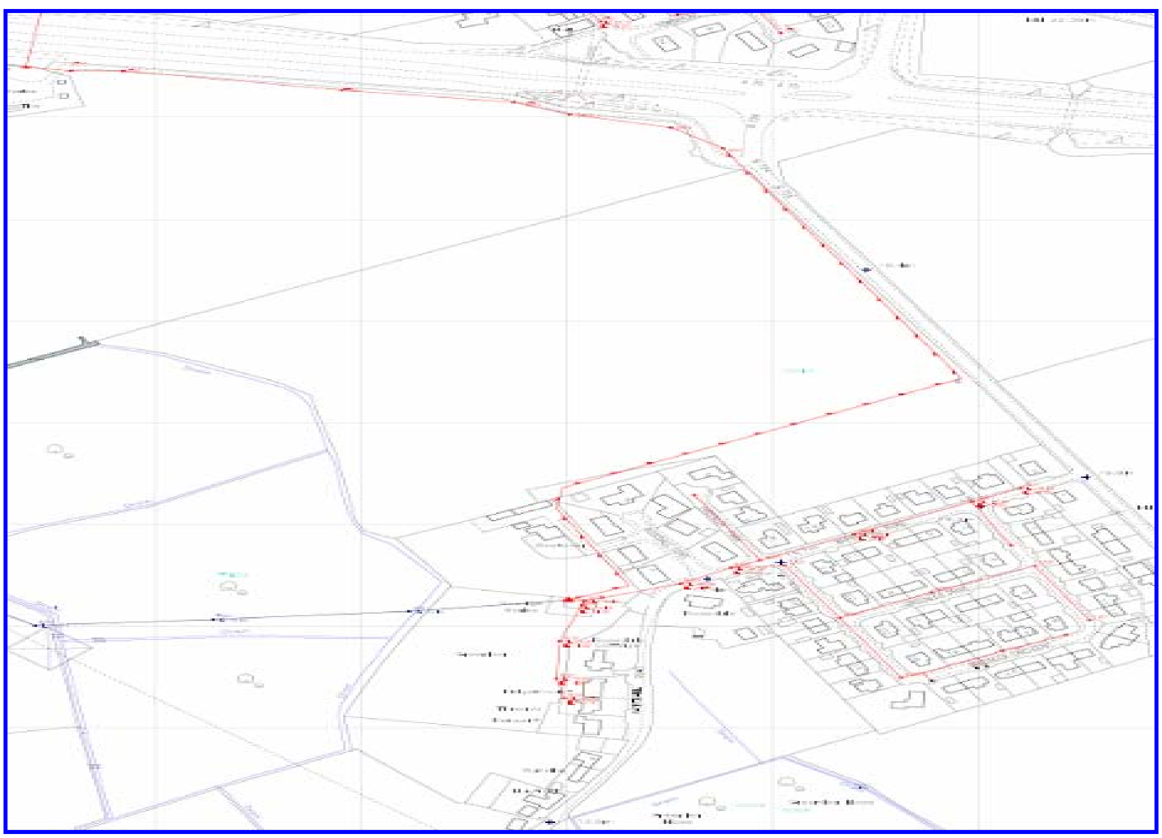

Figure 1. Zones of surface water contribution in the South Collin catchment – South area on left and including the North area on the right.

The volumes and durations of surface water removed from designated zones in Figure 1 are shown in Table 1 over a 1 in 1 year 60 minute duration storm event. The financial cost of each scenario is also given.

Baseline Flow

The baseline flow is the flow from an area under current conditions has the highest proportion of surface water inflows. Two events were investigated: the 1 in 1 year and the 1 in 30 year storm events, each of 60 minutes duration. These two events allowed comparisons to be made. From the initial results it is evident that there is a considerable financial benefit which could be achieved by not passing forward surface water.

Table 1. Surface water removal from designated zones in the South Collin drainage catchment (1 in 1 year event).

Surface Water in Designated Zones in South Collin Drainage Catchment Area	Volume Passed Forward (m^3)	Duration (h)	Power cost (£)
Baseline	140	2.6	2.03
Remove Zone A	135	2.5	1.95
Remove Zone B	108	2.0	1.56
Remove Zone C	117	2.17	1.69
Remove Zone D	99	1.83	1.43
Remove Zone E	126	2.33	1.82
Remove all Surface Water	23	0.43	0.34

The exercise was repeated for a 1 in 30 year event of the same duration (60 minutes) and the results are shown in Table 2.

Table 2. Surface water removal from designated zones in the South Collin drainage catchment (1 in 30 year event).

Surface Water in Designated Zones in South Collin Drainage Catchment Area	Volume Passed Forward (m^3)	Duration (h)	Power cost (£)
Baseline	257	4.8	3.75
Remove Zone A	256	4.7	3.67
Remove Zone B	211	3.9	3.04
Remove Zone C	216	4.0	3.12
Remove Zone D	198	3.7	2.89
Remove Zone E	243	4.5	3.51
Remove all Surface Water	23	0.43	0.34

The volumes and durations of surface water removed from the designated zones in Figure 1 over a typical year (a dataset with 168 storm events) were estimated and the results are given in Table 3.

Table 3. Annual surface water removal from designated zones in the South Collin drainage catchment.

Surface Water in Designated Zones in South Collin Drainage Catchment Area	Total Volume Passed Forward (m^3)	Duration (h)
Baseline	19,550	340
Remove Zone A	18,350	317
Remove Zone B	15,000	256
Remove Zone C	17,350	299
Remove Zone D	15,800	271
Remove Zone E	17,650	305
Remove all Surface Water	3,000	45

The annual power costs for 2010 and a predicted annual power cost index linked (3.5%) showing the cumulative financial expenditure up to 2035 for each scenario can be seen in Table 4.

Table 4. Annual power costs for designated zones in the South Collin drainage catchment.

Surface Water in Designated Zones in South Collin Drainage Catchment Area	Annual Power Cost (£) 2010	Net Present Value Power Cost (£) 2035	Cumulative Cost (£)
Baseline	265		10,300
Remove Zone A	247		9,630
Remove Zone B	199		7,780
Remove Zone C	233		9,080
Remove Zone D	211		8,230
Remove Zone E	237		9,270
Remove all Surface Water	35		1,200

1 in 1 Year Storm Event, of 60 minute duration

The Baseline Flow at the pumping station was $140m^3$. Various scenarios were run, each reducing the contributing area and reduced to $23m^3$ with all surface water removed. The power cost to transport the total flow during this storm event was £2.03. This reduced to £0.34 when all surface water was removed, a saving of £1.69 (83%).

1 in 30 Year Storm Event, of 60 minute duration

The Baseline Flow at the pumping station was 257m. This reduced to $23m^3$ with all surface water removed ($234m^3$ reduction or 91%). Similarly the power costs for pumping were reduced from £3.75 to £0.34 (91%).

Typical Year, 168 Storm Events

The third assessment concentrated on a typical year which identified 168 storm events over the course of a typical year. The analysis addressed only the storm events since, during normal operation in dry weather, no surface water is pumped. The total flow at the pumping station over the 168 storm events was $19{,}350m^3$. By removing all of the surface water, the flows being passed forward by the pumping station equates to $2{,}900m^3$ (reduction of 85%).

The assessment using 168 storm events for a typical year identified a significant difference between the pumped flows with and without surface water, causing an avoidable financial expenditure. To pump baseline flow over these 168 events incurred a cost of £265 as opposed to a cost of pumping the dry weather flow at £35 (reduction of 87%).

It is clear that there is a considerable difference between the energy cost for pumping the baseline flow and the dry weather flow. However, the absolute values of flow and money are low and on the basis that a system contained only one pumping station, no action would be taken unless other drivers applied, and no transition would occur.

Retrofitting SUDS Costs

Whilst the volumes of surface water and the SPS's financial savings have been identified the cost of retrofitting of SUDS in South Collin requires investigation and determination.

The aspects of the Treatment Train approach and their costs have been collated in Table 5.

Table 5. Treatment Train Approach and Costs.

Treatment Train Approach	Item	Cost
Disconnection of Roof Drainage – Water Butts and Reuse	58 units @ £1,000	£58,000
Swales and Infiltration Trenches	875m @ £95 per m	£83,125
Surface Water Sewer Design and Build	1025m @ £135 per m	£138,375
Pond Design and Build	1Vt @ £128,000	£128,000
Total		**£407,500**

It is important to note that the costs itemised in Table 5 are estimates, which are subject to fluctuations in the competitive market place and may yield an improved price.

Future Vision 2035

The current profile is 2010 and the future view is 2035, 25 years hence. When predicting the financial implications for the future vision of 2035, the figures from Table 4 were index linked at 3.5%. The annual power cost in 2035 for pumping the baseline flow was £600 and the dry weather flow £60. The total energy cost of pumping the baseline flow over the 25 year period (2010 to 2035) was £10,300 (€12,050), as opposed to pumping the dry weather flow only over the same period at £1,200 (€1,400).

Comparison of SPS Savings and Retrofit SUDS Costs

The financial, social and environmental benefits achieved through the removal of surface water entering the combined sewer system are substantial. However as previously discussed the cost of implementing a retrofit scheme is significant.

It is apparent form the data obtained through the modeling investigation and the detailed design of retrofitting a variety of SUDS measures that it is cost prohibitive. An important assertion is that the social and environmental benefits achieved are extremely difficult to put into monetary terms and should not therefore be discounted without further investigation and discussion.

Implications of the Consecutive Pumping of Surface Water

Currently at a number of locations across Scotland, surface water is pumped several times in order to receive treatment at the Wastewater Treatment Works. This leads to a considerable and unnecessary financial burden on the Water Authority because of the costs of pumping. The data from Collin was used to identify the financial implications of comparable SPS receiving similar flows to those at Collin SPS and operating in sequence terminating in discharge at the WwTW. This scenario was then modeled so that there were eight SPS in sequence. This set up (shown conceptually in Figure 2) reflects the current systemic operation of the pumping station regime operating in Edinburgh, the capital city of Scotland.

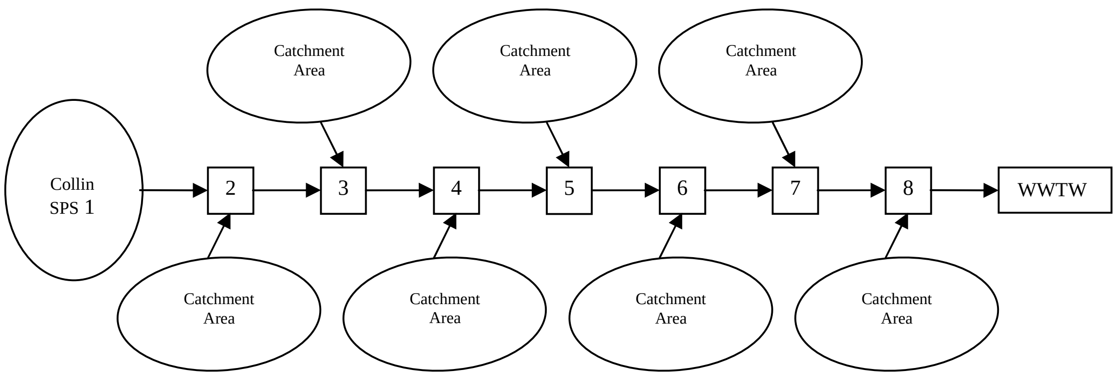

Figure 2. Zones demonstrating the hypothetical sequential pumping of surface water.

A number of assumptions were made for each pumping station and were determined to be constant such as; pump size, power rating, wet well dimension, operation, catchment area, length of rising main, static head, friction loss, pipe diameter, pipe roughness.

Table 5. Implications of unnecessary pumping of surface water reflected in power costs.

SPS	Baseline Annual Costs £	Net Present Value 2035 Costs £	Baseline Cumulative Costs £	Removal SW Annual Costs £	Net Present Value Removal SW 2035 Costs £	Removal SW Cumulative Costs £	2010 Annual Savings £	Net Present Value 2035 Savings £	2010 – 2035 Cumulative Savings £
1	**316**			**48**			**268**		
2	**633**			**102**			**531**		
3	**828**			**156**			**672**		
4	**994**			**211**			**783**		
5	**1,148**			**268**			**880**		
6	**1,296**			**326**			**970**		
7	**1,435**			**383**			**1,052**		
8	**1,561**			**439**			**1,122**		
Total	**8,211**			**1,933**			**6,278**		

The financial implication of consecutively pumping surface water from one pumping station to the next prior to receiving treatment is identified in Figure 5. Similarly the future projections of this cost have been identified.

DISCUSSION

Reducing Energy Costs

The annual electricity bill to Scottish Water is currently around £40 million (€34.1 million) and the company is committed to identifying methods to reduce this expenditure. By investigating the South Collin drainage catchment and determining the volumes and durations of the pumping station operation, it was possible to calculate the power costs and the potential financial savings which could be achieved through the removal of surface water from the network. This example has focused primarily on the power requirements of the current situation and varying scenarios of removing the significant amounts of surface water entering the system.

At any pumping station there are several other factors which contribute to the total cost to the drainage utility including; Chemicals, Labour, Maintenance, Spares, Contracts, Property, Consumables, Gas, Water, Telecoms, Sludge Transport, Third Party and Vehicle Costs.

It is clear that there is a significant financial burden on the water authority to transport the surface water runoff for treatment and it would be desirable to reduce energy charges. While there are clear savings to be made for the drainage utility by removing the surface water, the capital costs of implementing the works required to remove the surface water are significant. Frequently, short term costs of new works and equipment outweigh the longer term benefits and no action is taken.

Whilst there is dialogue between Scottish Water, Scottish Environment Protection Agency (SEPA), Scottish Government and Local Council Authorities, there is an obligation for all stakeholders to commit to a longer term vision that benefits communities in a more sustainable manner. Benefits of reduced surface water flows have been well researched and documented previously (Dennison, 1996) with the main items identified below.

Water Authority Benefits

In addition to the financial saving to be achieved at the pumping station, substantial benefits to the Water Authority could also be achieved. These include; the effect of the reduced volume requiring treatment at the wastewater treatment works, increased carrying capacity of the network allowing for future developments to be connected, reduced impact of urbanization as well as the reduction in carbon emissions with the importance on climate change (Semandeni-Davies et al, 2007).

Social Benefits

The provision of a pond for example will provide the local residents with an added amenity value. It has been identified (Heal et al, 2004) that the local people will frequently suggest establishing picnic areas with benches etc around ponds in order to further improve the amenity of the area. With an improved recreational value and landscaping a more positive sense of well-being can be created.

From a down-to-earth standpoint, the use of swales and permeable paving for example in conflate with footpaths will allow the local residents not to be subjected to puddles.

A reduction in sewer flooding risk whether internal or external will improve the level of service to the Scottish Water's customers and issues relating to public health. Perhaps more importantly however, the emotional impact and the sever consequences brought about by the effects of flooding should not be underestimated.

Environmental Benefits

There are substantial environmental benefits which can readily be achieved and have been well documented. Such as a reduction in the frequency of discharges to the receiving watercourse and bathing water's which will provide an improvement in water quality and to the surrounding habitat. This can lead to habitat creation and/or enhancement, whilst increasing blue / green public areas and wildlife corridors. Similarly the morphology of the watercourse will be protected amongst others.

Recent Innovation

In very many cases little progress is made towards a more environmentally sound solution because the short term costs outweigh the benefits. Historically the interventions needed have been clear but they have not been implemented because the financial obstacles have seemed to be insurmountable. One small step forward has been the recent innovative approach taken by Scottish Water using Variable Speed Drive Pumps (Moore, G, 2011). Whilst pumping efficiency is key, reliability is vital and by adopting these VSD pumps a number of additional benefits can be achieved, such as reduced blockages, disruption, call out's maintenance and health and safety risks.

SWITCH Transitioning

The SWITCH Transitioning approach provides a framework which enables all stakeholders to be engaged in the issue and to include additional drivers such as emerging technologies, governance and public polices framed to change public priorities. A pillar of the SWITCH ethos is to move away from the traditional method for dealing with drainage issues, namely the conveyance of stormwater flows as rapidly as possible utilising large diameter underground piped systems to a more storage-orientated attitude of attenuating and re-using the rainwater on site or locally. The high costs of maintaining and improving existing infrastructure provides an opportunity to investigate the implementation of an alternative methodology.

Series pumping accentuate the issue

The scenario examined in this project was to use data from a known location where a network model already existed. The model was replicated to give an arrangement where the same pumping station was in series up to eight times and to identify the point when the costs of pumping the water again and again might be such that making a transition would become financially advantageous. The modeling and scenario testing process above is standard practice in the evaluation of projects and, for a single SPS, implementing the changes needed was shown to reduce the cumulative power cost from £10,300 to £1,200 over a 25year period.

The data obtained from the arrangement with eight pumping stations in sequence showed that financial savings could be considerable.

The eight SPS arrangement each had an annual running cost of £9,540 with the total future annual running cost of £21,600. This represents a total cumulative running cost over 25yrs, based on electricity costs alone, of £371,300. By removing the surface water component, the power costs were reduced to a total current annual running cost of £1,260 rising to £2,860 in future giving total cumulative running cost over 25yrs of £49,100.

If the surface water component is removed the total current annual saving for running the eight SPS is £8,280. This provides a total future annual saving for operating the sequential pumping station arrangement of £18,740. Overall this will provide a total cumulative saving for the water authority of £322,200, (€377,700) over the 25year period. This is a noteworthy saving which could be readily achieved.

FUTURE WORK

It is expected that future energy costs will rise significantly ahead of inflation. The modeling will take different energy cost scenarios and investigate the optimum number of pumping stations in sequence which will produce the saving which makes investment worthwhile. A typical question in this process is '..with ageing infrastructure, when is the optimum moment to change the pumps to operate more efficiently at the reduced foul flow only flow rates'. It is this opening which will be under future investigation to provide evidence to assist in creating the 'cities for the future'.

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APPENDIX 2

Workshop Presentation, Questionnaire and Graphical Results

Removal of surface water from combined sewer systems using a transitioning approach

By

Mr Kerry W. S. Smith

Contents

INTRODUCTION

Scottish Water is the single largest user of power in Scotland and is faced with two challenges:

How to reduce the current consumption levels

Increasing energy prices over time.

The research hypothesises that the removal of surface water from a typical combined sewer system is justified by focusing on the energy consumption required to pump increased volumes during storm events and applying a transitioning approach.

1.0 INTRODUCTION

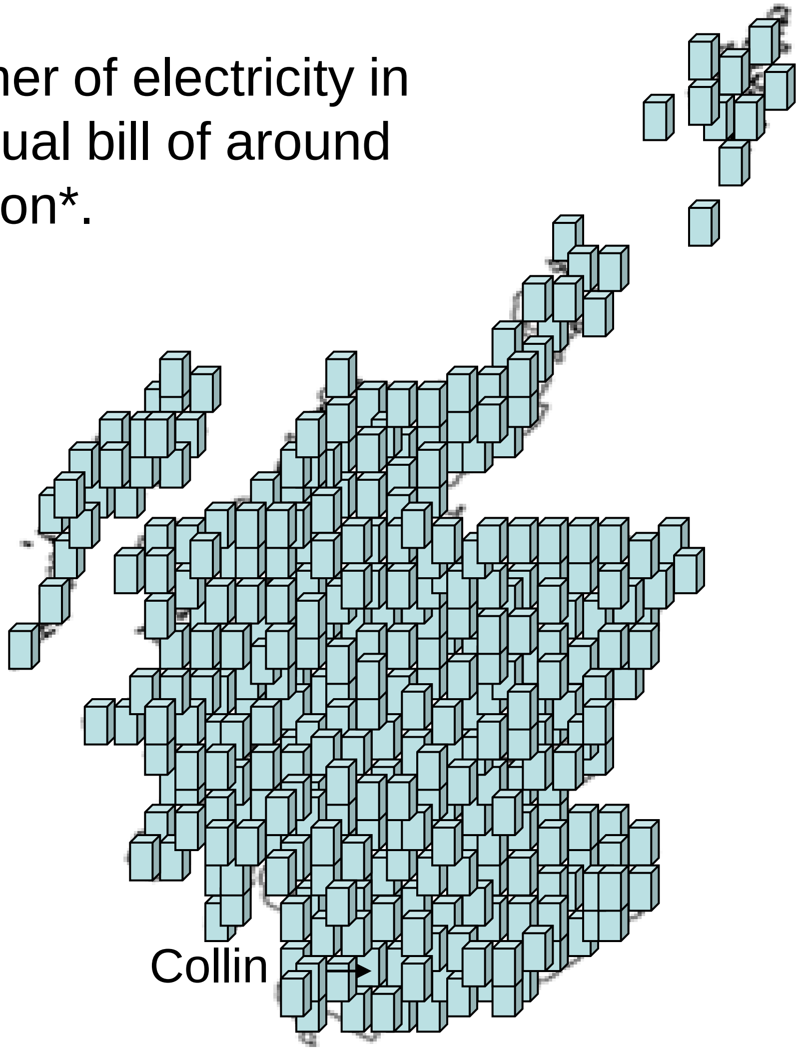
The principle is that with existing techniques it is not possible to move towards a 'new world' whereby the infrastructure will have a much lower operational energy cost.

The transformation will require upfront financial expenditure which, at the outset, will provide little return yet one accumulated will bring about increasing financial, social and environmental benefits for a variety of stakeholders

With 2,100 Pumping Stations supplying 1,898 wastewater treatment works, several will operate in sequence thus resulting in potentially even greater benefits a transition in thinking becomes even more necessary.

1.0 INTRODUCTION Cont.

Single largest consumer of electricity in Scotland with an annual bill of around £40 million*.



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2.0 CURRENT SITUATION

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There is a considerable financial expense through maintenance, conveyance and treatment of combined flows to Scottish Water.

But where do you start when the problem is not 'critical' and an initial investment is required?

Figure 1. A Generic Wastewater Treatment Works

Figure 2. Large Storage Solutions

3.0 IMPROVEMENT DRIVERS

Drivers for Transition:

- Reduction in:
    - Energy consumption
    - Capital and operational expenditure
    - Sewer flooding risk (internal and external)
    - Combined Sewer Overflow Discharges

- Increase in:
    - Ability to support development
    - Environmental quality improvements
    - Habitat creation, biodiversity and amenity

4.0 SWITCH TRANSITION FRAMEWORK

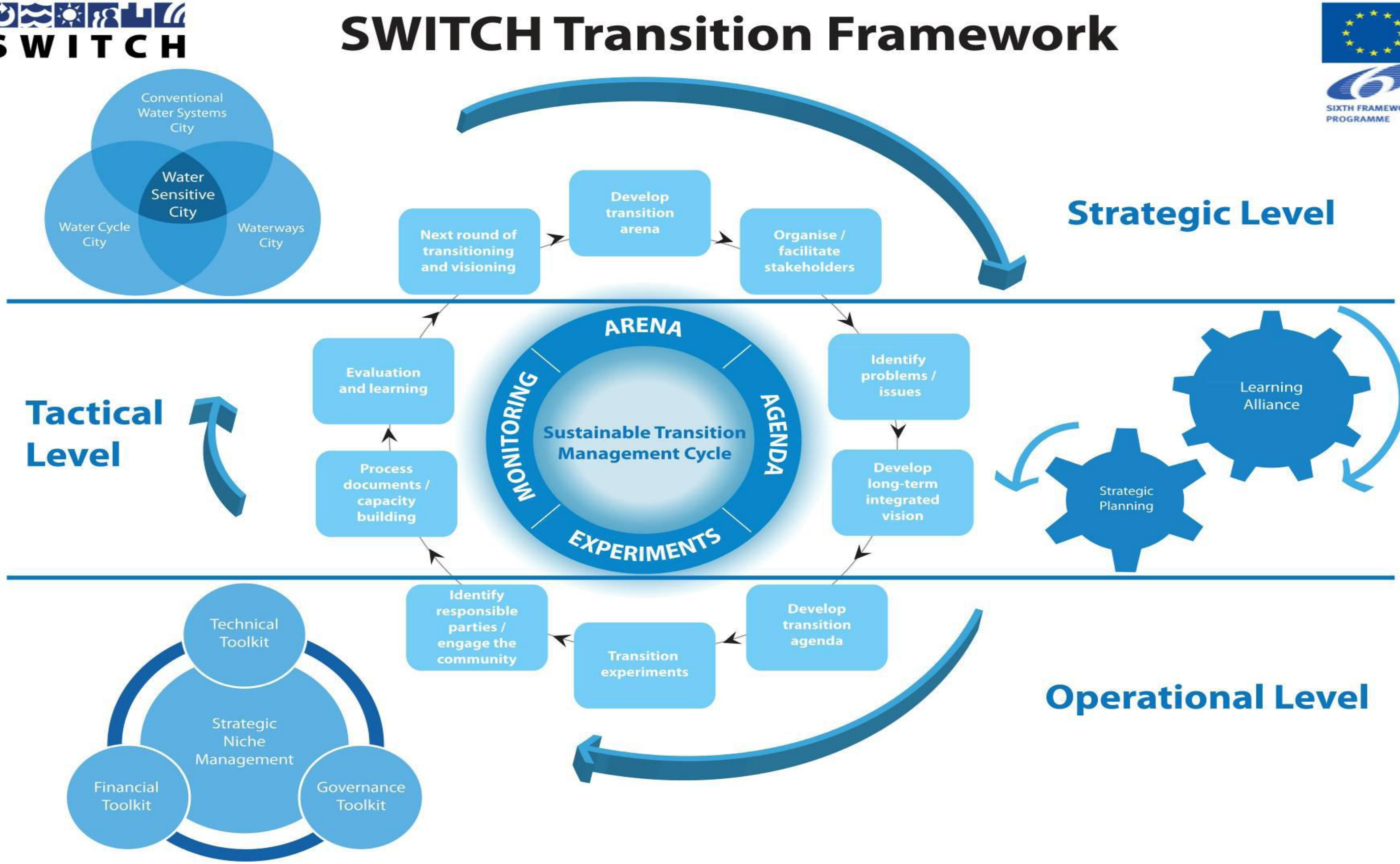


Figure 3. The SWITCH Transition Framework

5.0 TRANSITION EXPERIMENT

Figure 4. South Collin Combined Sewer Network

- The volumes and durations of the pumping station operation were determined.

- Varying scenarios were modelled and Surface Water iteratively removed.

- The power costs were established.

- Potential financial savings were calculated.

5.0 TRANSITION EXPERIMENT Cont.

Table 1 Cumulative costs of Pumping Surface Water (£)

Surface Water in Designated Zones in South Collin Drainage Catchment Area	Annual Power Cost (£) 2010	Cumulative Cost (£) to 2035
Current Operation	**265**	**4,367**
Remove Zone A	247	**4,071**
Remove Zone B	199	**3,280**
Remove Zone C	233	**3,840**
Remove Zone D	211	**3,477**
Remove Zone E	237	**3,906**
Remove all Surface Water	**35**	**577**

Table 2 Retrofit Costs (£)

Disconnection Solution	Item	Construction Cost (£)
Raingardens	90 units @ £2,614	**235,260**
Water Butts and Reuse	90 units @ £49.95	**4,495**
Swales and Basin	Swale £6,775 and Basin £11,367	**18,142**
Surface Water Sewer Design and Build	1430m @ £91.39 per m	**130,682**
Permeable Paving	1430m @ £154	**220,424**

While there are clear savings to be made, the capital costs of implementing the works required are significant.

Frequently, short term costs of new works and equipment outweigh the longer term benefits and no action is taken.

6.0 CONSECUTIVE PUMPING

The figure below shows the theoretical operation for Collin reflecting the multiplying impact of consecutively pumping surface water prior to treatment and mirrors the regime currently operating throughout Edinburgh, Midlothian and East Lothian.

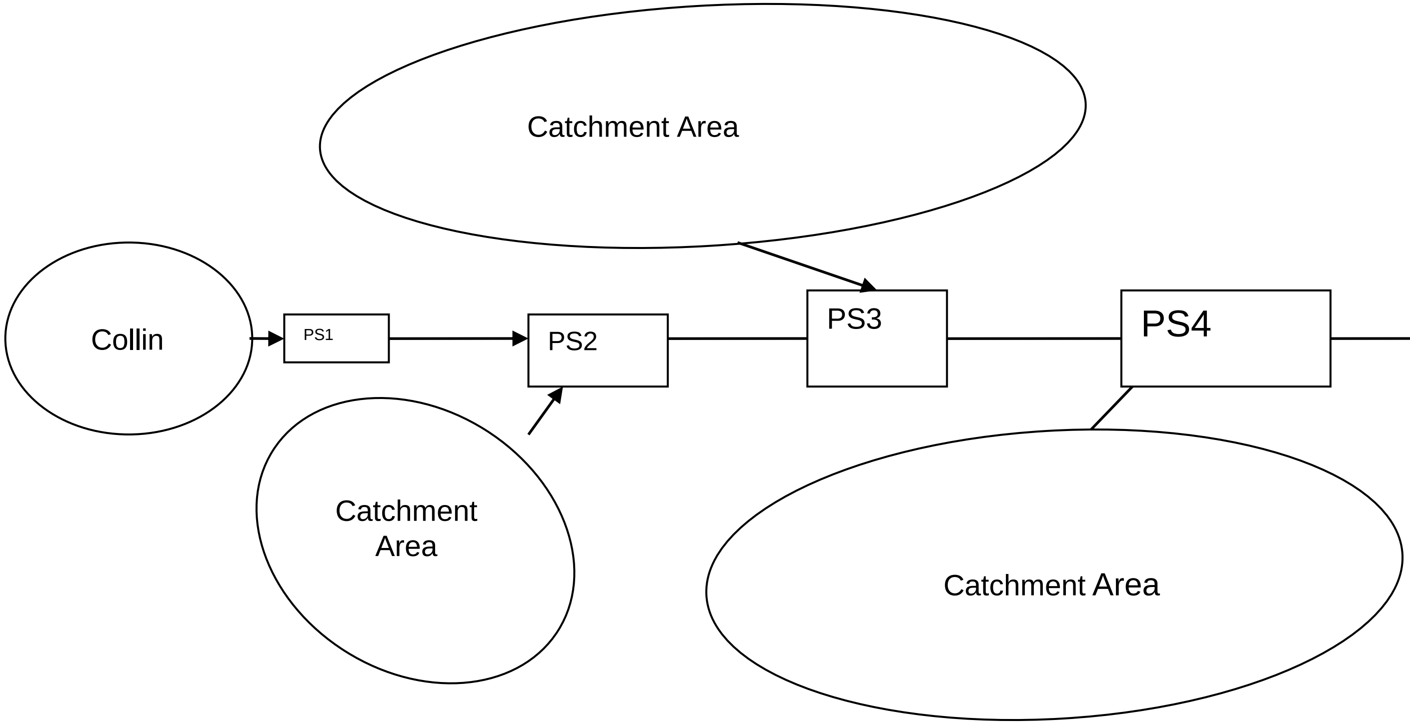


Figure 4. Demonstrates The Hypothetical Sequential Pumping Of Surface Water.

7.0 DISCONNECTION EXAMPLES

An example of a successful transitional programme of water sensitive design towards improving the local environment is in the City of Portland, USA (Mazzotta, 2007).

The water authority offered customers as part of its Clean Rivers Rewards project (Hottenroth, 2008), a discount where they can save money and improve the environment by disconnecting their surface water discharges from the combined sewer systems.

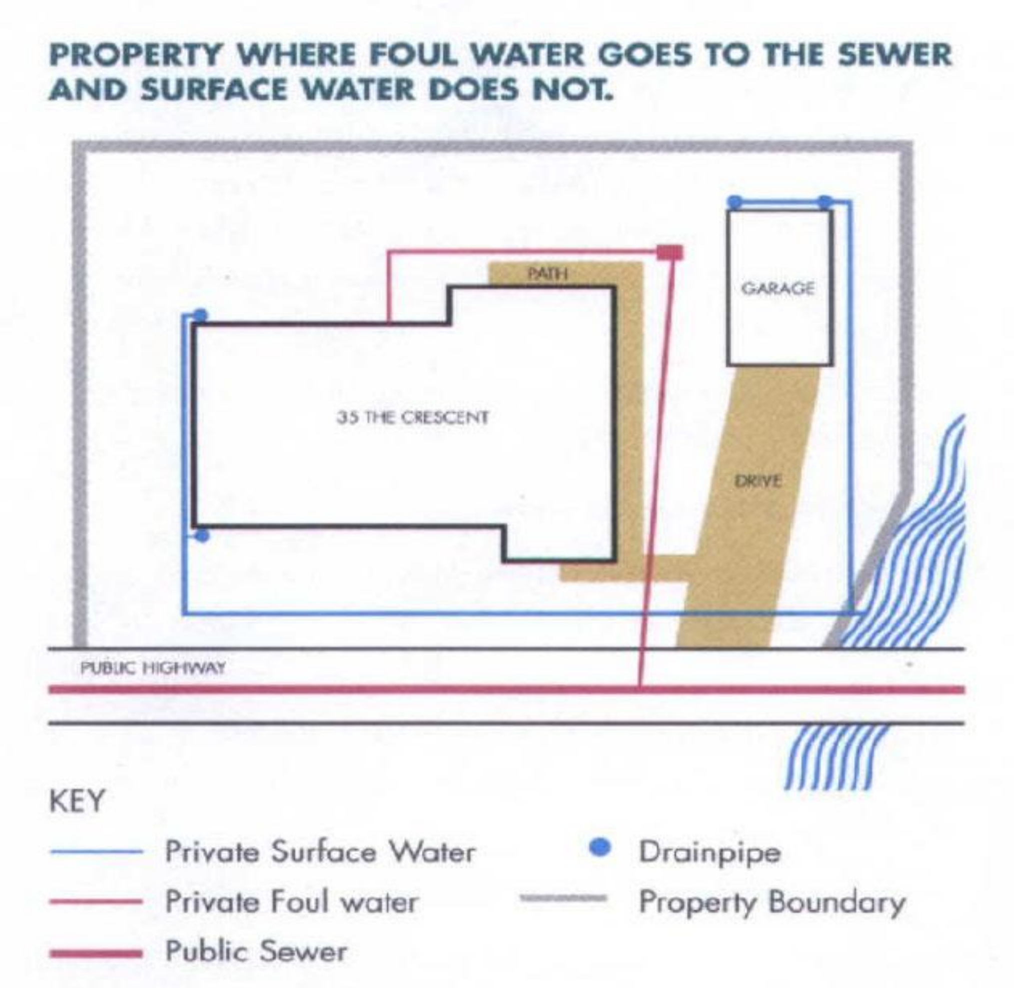
This promotional scheme operated between 1993 and 2011 involved 56,000 homeowners and resulted in 1.3 billion gallons of surface water being removed on an annual basis from the combined sewer system (www.portlandoregon.gov, 2013) with a reduction in local peak CSO volume by 20%.

8.0 DOWNSPOUT DISCONNECTION DEVICES

Figure 5. Standard Downspout Disconnection Device

Figure 6. Aesthetically Designed Downspout Disconnection Device

9.0 DISCONNECTION REBATE SCHEME



Yorkshire Water advises their customers that by disconnecting their properties surface water drainage, and by demonstrating the flows discharge elsewhere, the customer can receive an annual rebate off their wastewater services charge of £45.96 or at least 10% of the total bill.

Figure 8. Information On Disconnection Requirements By Yorkshire Water (www.yorkshirewater.org, 2015)

10.0 WASTEWATER CHARGE IN THE CITY OF EDINBURGHS COUNCIL TAX

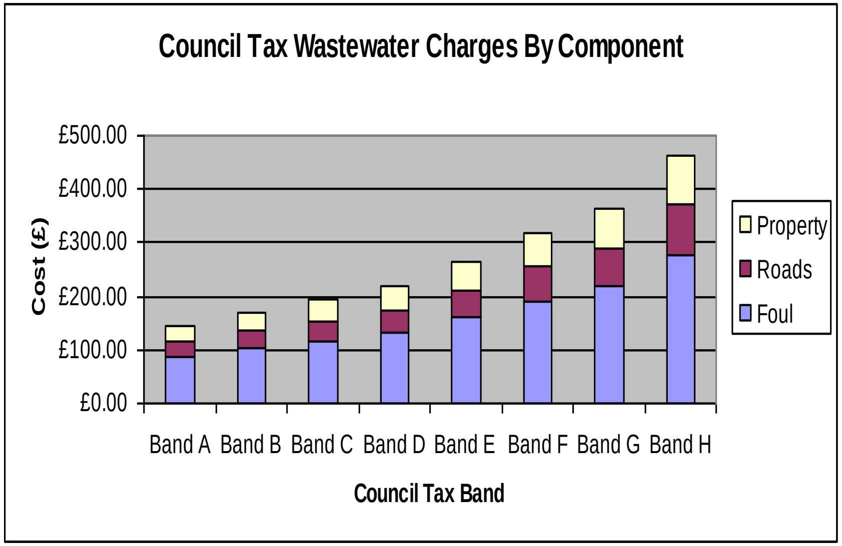


Figure 9. Wastewater charge by Council Tax Banding 2013-2014

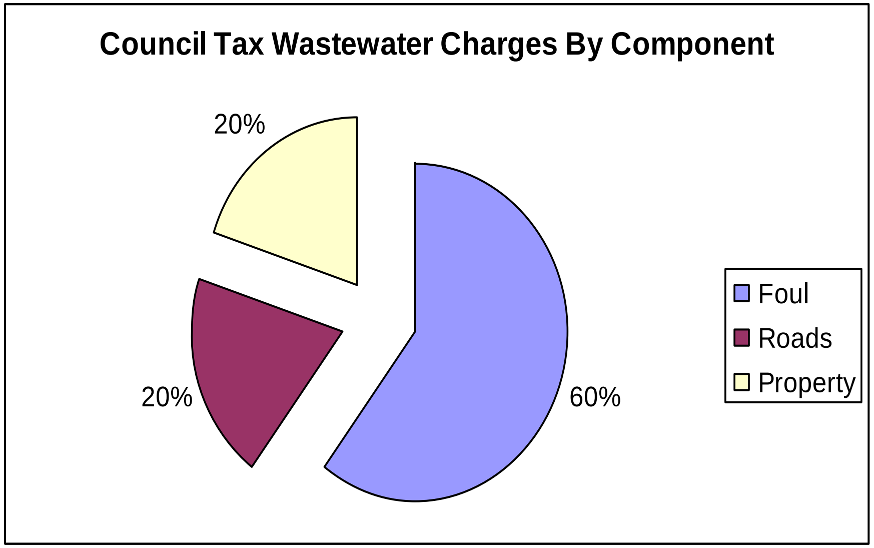


Figure 10. Percentage Proportional Cost of Surface Water

For an average property, Band E, Scottish Water could advise their customers that by disconnecting their properties surface water drainage, the customer could receive an annual rebate off their wastewater services charge of £51.11 or at least 10% of the annual bill.

11.0 KEY STAKEHOLDERS

Key Stakeholders who can make the transition happen are:

- Scottish Government
- Scottish Water
- The Water Industry Commission for Scotland
- Scottish Environment Protection Agency
- Consumer Focus Scotland.

12.0 QUESTIONNAIRE

Surface water accounts for 90% of the flows during storm conditions of which 43% was identified in the modelling experiment as originating from Roofs.

This questionnaire seeks to obtain information from key stakeholders on how best to propose a future vision of communities, through the optimisation of wastewater techniques through the removal of surface water flows.

By presenting information on:

1. Surface Water
2. Stakeholders
3. Transitioning Approach

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12.0 QUESTIONNAIRE

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Question 1. Information

Which departmental description best describes where you work, please only tick one?

DEPARTMENT	X
Asset Infrastructure Management	
Finance	
Energy	
Administration	
Legal	
Environmental	
Commercial	
Policy and Regulation	
Customer Connections	
Operations	

12.0 QUESTIONNAIRE

Question 2. Surface Water

Do you think surface water flows in the combined sewer system should be removed?

RESPONSE	x
YES	
NO	
Neither Yes/No	

12.0 QUESTIONNAIRE

Question 3. Surface Water

Do you think surface water flows in the combined sewer system should be reduced?

RESPONSE	x
YES	
NO	
Neither Yes/No	

12.0 QUESTIONNAIRE

Question 4. Surface Water

Do you think the removal/reduction of surface water would provide financial benefits?

RESPONSE	x
Strongly Agree	
Agree	
Neither Agree nor Disagree	
Disagree	
Strongly Disagree	

12.0 QUESTIONNAIRE

Question 5. Surface Water

What do you think about the following statement?

The Removal Of Surface Water From The Combined Sewer Network Prior To Pumping Is A Necessity Not A Luxury.

RESPONSE	x
Strongly Agree	
Agree	
Neither Agree nor Disagree	
Disagree	
Strongly Disagree	

12.0 QUESTIONNAIRE

Question 6. Surface Water

Do you think the removal/reduction of surface water would provide environmental benefits?

RESPONSE	X
Strongly Agree	
Agree	
Neither Agree nor Disagree	
Disagree	
Strongly Disagree	

12.0 QUESTIONNAIRE

Question 7. Surface Water

Do you think the removal/reduction of surface water would provide social benefits?

RESPONSE	x
Strongly Agree	
Agree	
Neither Agree nor Disagree	
Disagree	
Strongly Disagree	

Question 8. Stakeholders

Who do you think is responsible for reducing surface water flows, please tick more than one if necessary?

RESPONSE	x
Water Industry Commissioner for Scotland	
Scottish Government	
Consumer Focus Scotland	
Scottish Water	
Scottish Environment Protection Agency	
Everyone	
Other, please state:	

12.0 QUESTIONNAIRE

Question 9. Stakeholders

Of the key stakeholders identified, please rank them in order of importance of making the ultimate decision to implement the Disconnection Rebate Scheme? 1 is the most important with 5 being the least.

RESPONSE	X
Water Industry Commissioner for Scotland	
Scottish Government	
Consumer Focus Scotland	
Scottish Water	
Scottish Environment Protection Agency	

12.0 QUESTIONNAIRE

Question 10. Transitioning Approach

Do you think removing surface water from Customers Properties through the Disconnection Rebate Scheme is a key transitional step to achieving the vision of surface water free pumping stations?

RESPONSE	X
Strongly Agree	
Agree	
Neither Agree nor Disagree	
Disagree	
Strongly Disagree	
Please advise an alternative 1st step:	

12.0 QUESTIONNAIRE

Question 11. Transitioning Approach

Do you think the Transitioning Management Cycle is the correct approach to achieve the vision of surface water free pumping stations?

RESPONSE	x
Strongly Agree	
Agree	
Neither Agree nor Disagree	
Disagree	
Strongly Disagree	
Please suggest another:	

12.0 QUESTIONNAIRE

Question 12. Transitioning Approach

Please rank the factors that would influence you the most in supporting a project removing the surface water flows from the combined sewer network with 1 being the most influential to 7 being the least?

RESPONSE	x
Financial	
Environmental	
Legislation	
Political	
Health and Safety	
Social	
Other (Please Describe)	

12.0 QUESTIONNAIRE

Question 13. Transitioning Approach

Is a transition in the operation and utilisation of wastewater assets and infrastructure required?

RESPONSE	X
Strongly Agree	
Agree	
Neither Agree nor Disagree	
Disagree	
Strongly Disagree	
No Comment	

12.0 QUESTIONNAIRE

Question 14. Transitioning Approach Solution

Do you think an incentive scheme is necessary?

RESPONSE	X
Strongly Agree	
Agree	
Neither Agree nor Disagree	
Disagree	
Strongly Disagree	
Suggestions welcome:	

12.0 QUESTIONNAIRE

Question 15. Transitioning Approach Solution

Would you support the removal of surface water through the Disconnection Rebate Scheme?

RESPONSE	x
Strongly Agree	
Agree	
Neither Agree nor Disagree	
Disagree	
Strongly Disagree	

12.0 QUESTIONNAIRE

Question 16. Transitioning Approach Solution

Do you think a Disconnection Rebate Scheme would be successful?

RESPONSE	x
Strongly Agree	
Agree	
Neither Agree nor Disagree	
Disagree	
Strongly Disagree	

12.0 QUESTIONNAIRE

Question 17. Conclusion

Do you think that the removal of surface water from a typical combined sewer system is justified by focusing on the energy consumption required to pump increased volumes during storm events and applying a transitioning approach.

RESPONSE	x
Strongly Agree	
Agree	
Neither Agree nor Disagree	
Disagree	
Strongly Disagree	
Please suggest another:	

12.0 QUESTIONNAIRE

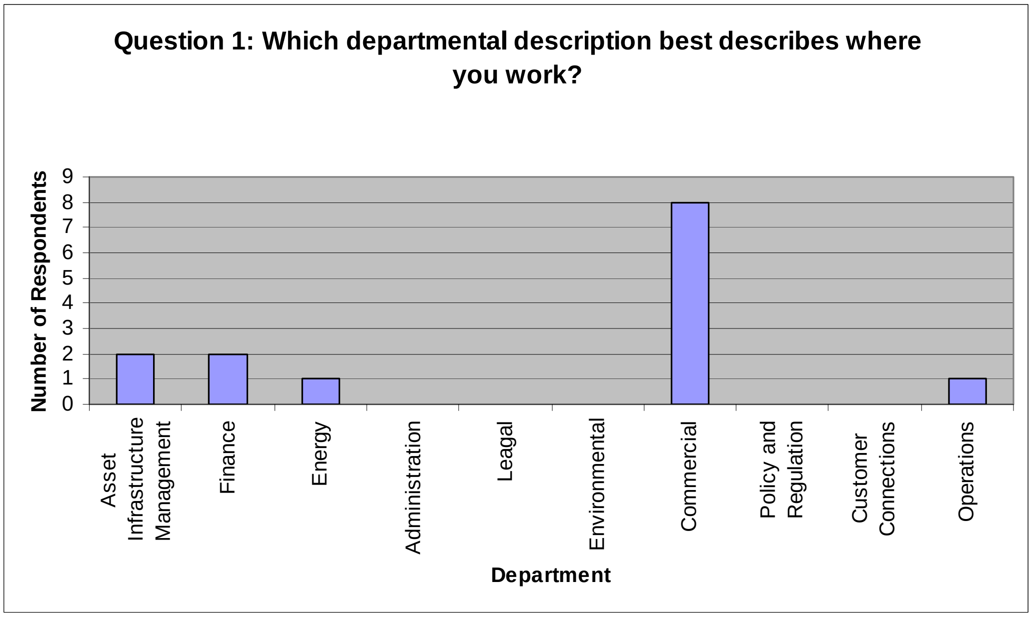
Question 18. Conclusion

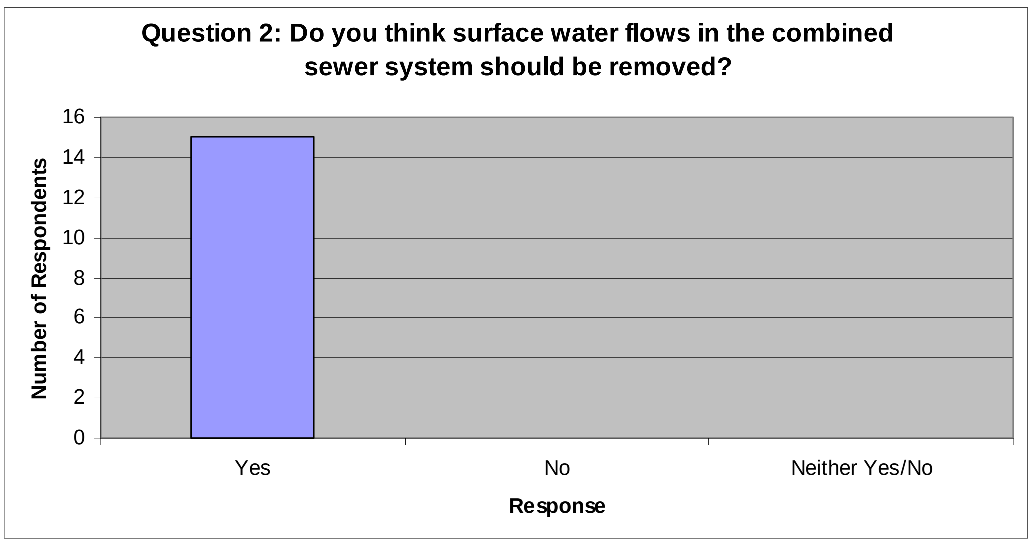
Do you think that the removal of surface water from a typical combined sewer system is justified by focusing on energy consumption, the potential financial, environmental, social benefits achievable and applying a transitioning approach.

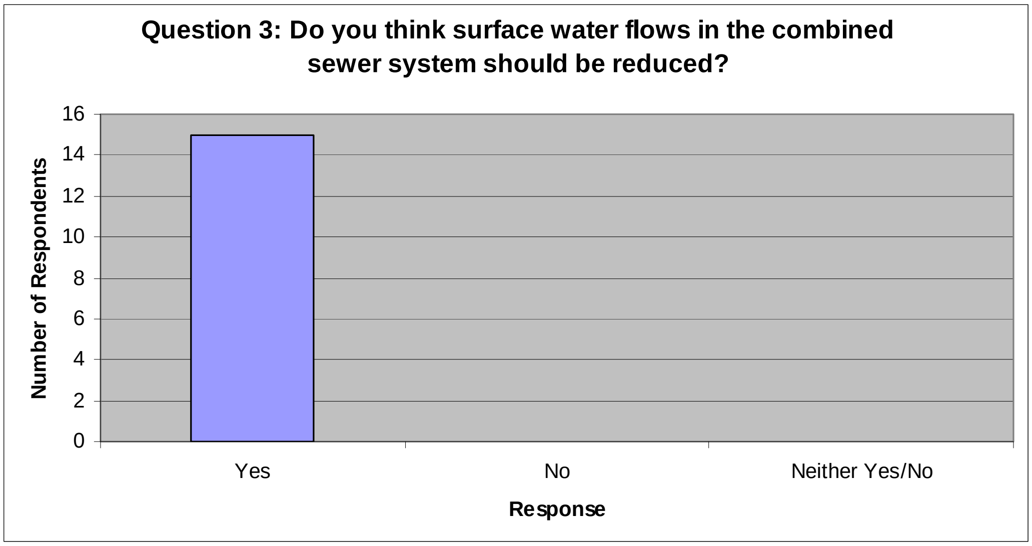
RESPONSE	x
Strongly Agree	
Agree	
Neither Agree nor Disagree	
Disagree	
Strongly Disagree	
Please suggest another:	

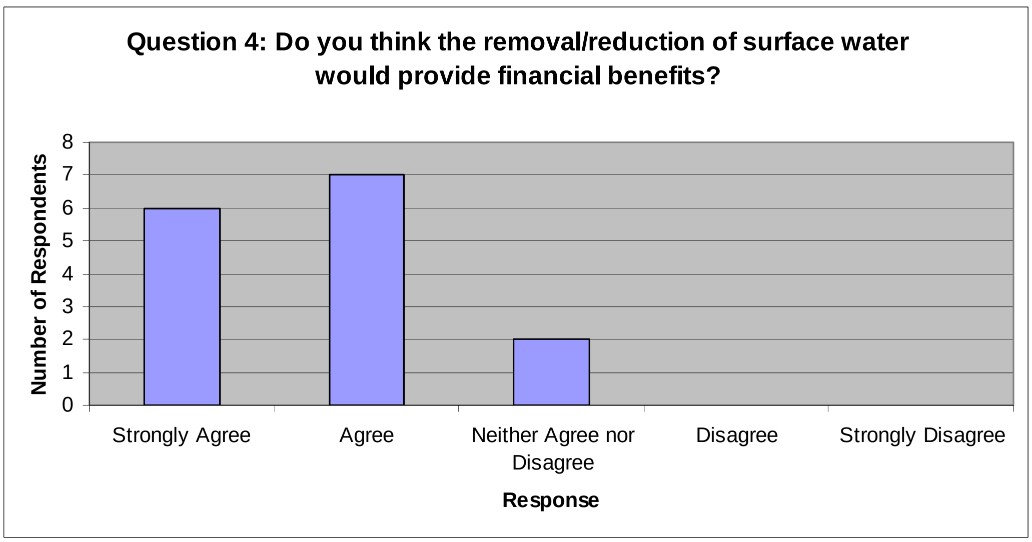
Thank you for your participation. I would be happy to share findings from this questionnaire and the research, for more information, please contact me on kerry.smith@scottishwaterhorizons.co.uk

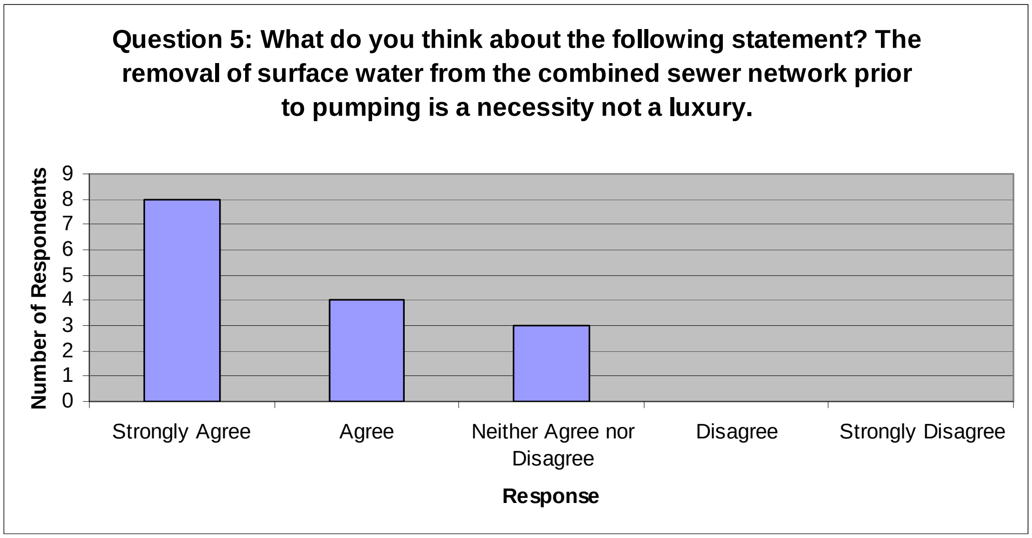
SUGGESTIONS WELCOME
If you have any suggestions how to improve the research please provide your comments here?

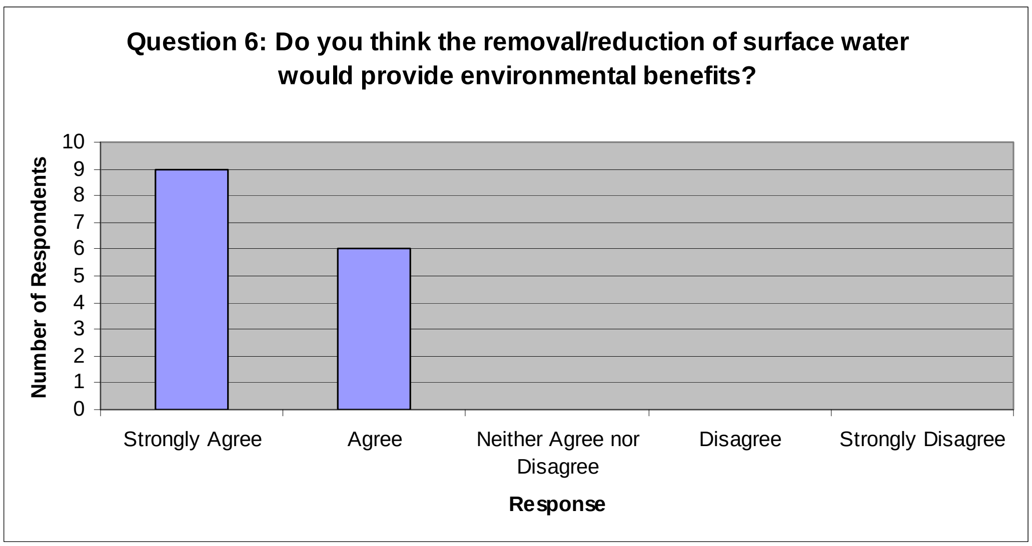

Question 1: Which departmental description best describes where you work?
Number of Respondents
0
1
2
3
4
5
6
7
8
9
Asset Infrastructure Management
Finance
Energy
Administration
Leagal
Environmental
Commercial
Policy and Regulation
Customer Connections
Operations
Department

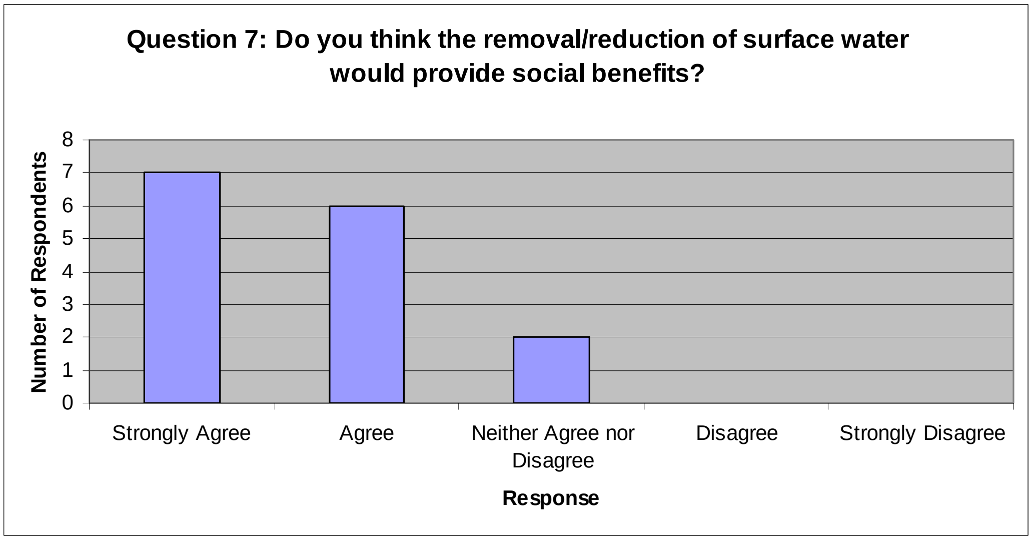

Question 2: Do you think surface water flows in the combined sewer system should be removed?
Number of Respondents
0
2
4
6
8
10
12
14
16
Yes
No
Neither Yes/No
Response

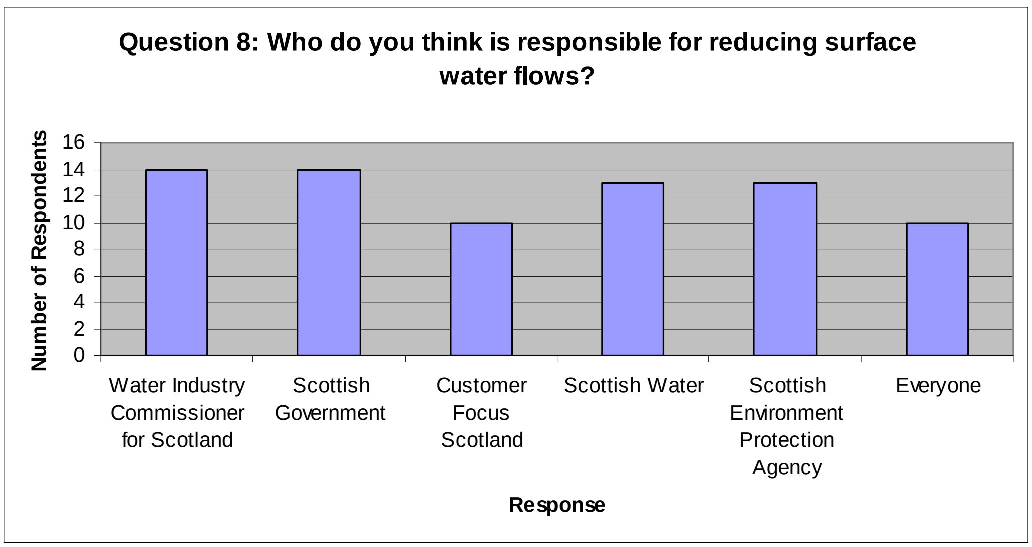

Question 3: Do you think surface water flows in the combined sewer system should be reduced?
Number of Respondents
16
14
12
10
8
6
4
2
0
Yes
No
Neither Yes/No
Response

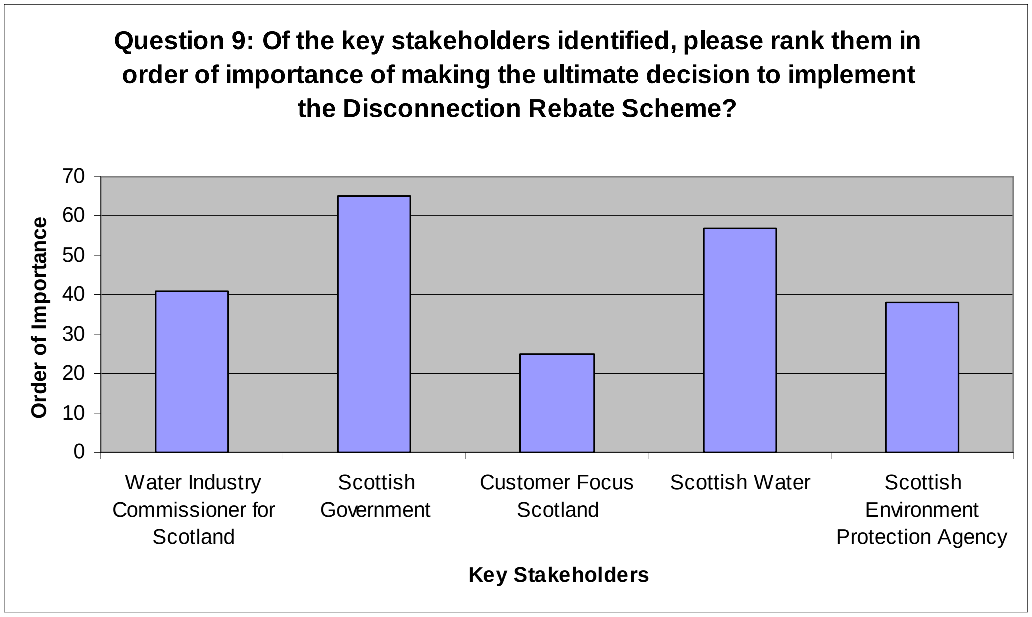

Question 4: Do you think the removal/reduction of surface water would provide financial benefits?
Number of Respondents
8
7
6
5
4
3
2
1
0
Strongly Agree
Agree
Neither Agree nor Disagree
Disagree
Strongly Disagree
Response


Question 5: What do you think about the following statement? The removal of surface water from the combined sewer network prior to pumping is a necessity not a luxury.
Number of Respondents
0
1
2
3
4
5
6
7
8
9
Strongly Agree
Agree
Neither Agree nor Disagree
Disagree
Strongly Disagree
Response

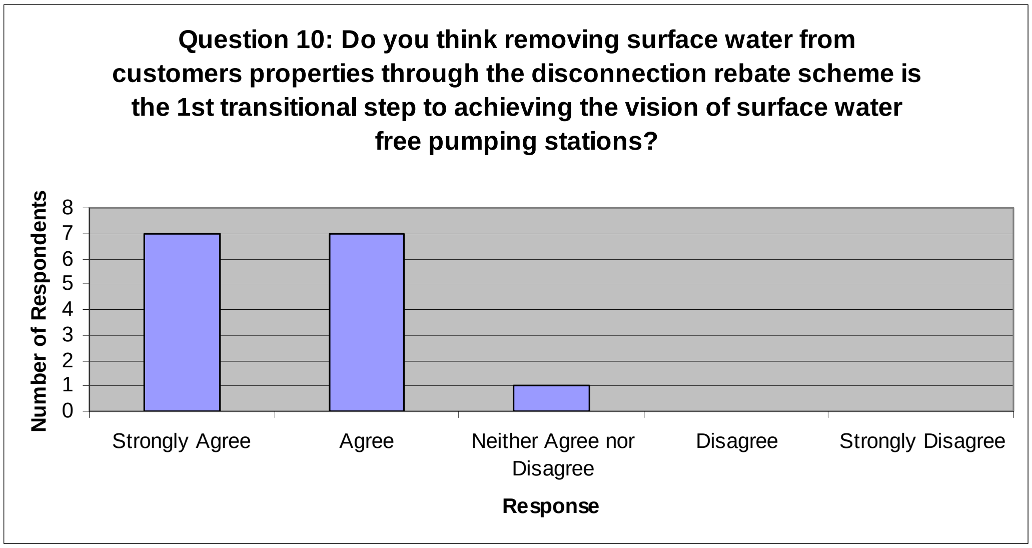

Question 6: Do you think the removal/reduction of surface water would provide environmental benefits?
Number of Respondents
0
1
2
3
4
5
6
7
8
9
10
Strongly Agree
Agree
Neither Agree nor Disagree
Disagree
Strongly Disagree
Response

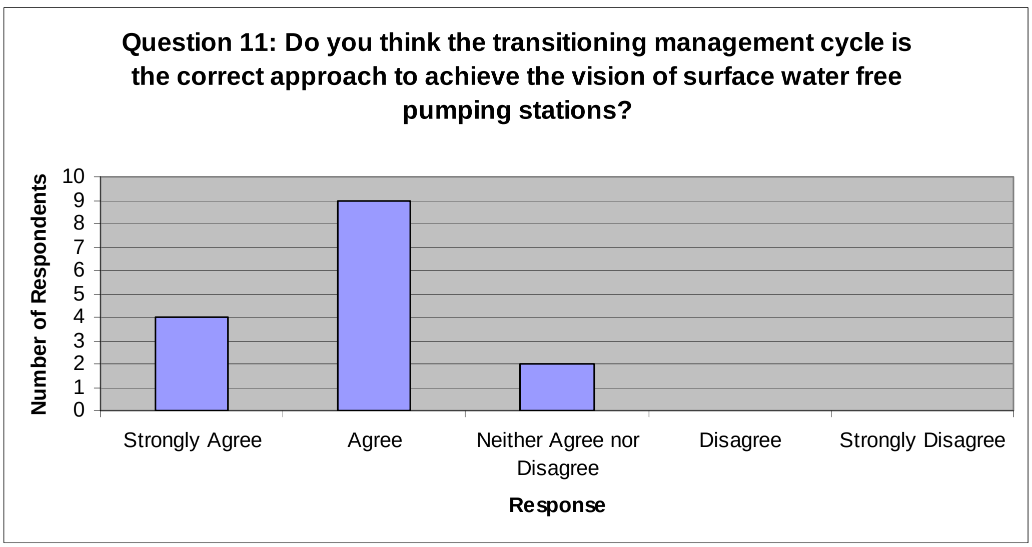

Question 7: Do you think the removal/reduction of surface water would provide social benefits?
Number of Respondents
0
1
2
3
4
5
6
7
8
Strongly Agree
Agree
Neither Agree nor Disagree
Disagree
Strongly Disagree
Response

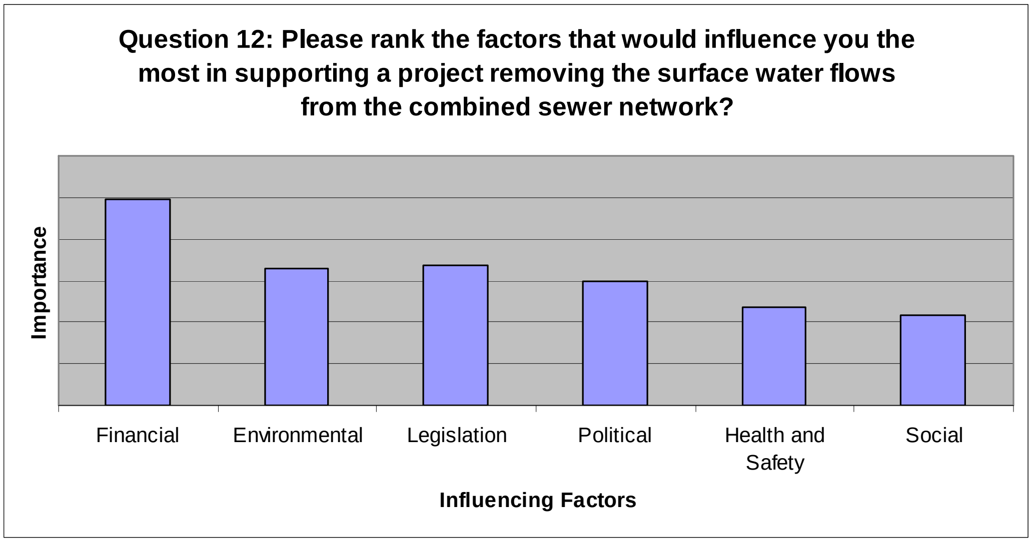

Question 8: Who do you think is responsible for reducing surface water flows?
Number of Respondents
0
2
4
6
8
10
12
14
16
Water Industry Commissioner for Scotland
Scottish Government
Customer Focus Scotland
Scottish Water
Scottish Environment Protection Agency
Everyone
Response



Question 9: Of the key stakeholders identified, please rank them in order of importance of making the ultimate decision to implement the Disconnection Rebate Scheme. Mode Information																
Key Stakeholder	Responses received															TOTAL
Water Industry Commissioner for Scotland	5	2	2	2	3	2	2	4	3	4	2	3	2	2	3	41
Scottish Government	1	1	1	1	1	1	1	5	1	1	1	2	3	3	2	65
Customer Focus Scotland	4	4	4	5	5	5	5	1	4	3	5	5	5	5	5	25
Scottish Water	2	5	3	3	4	4	3	3	2	2	3	1	1	1	1	57
Scottish Environment Protection Agency	3	3	5	4	2	3	4	3	5	5	4	4	4	4	4	38

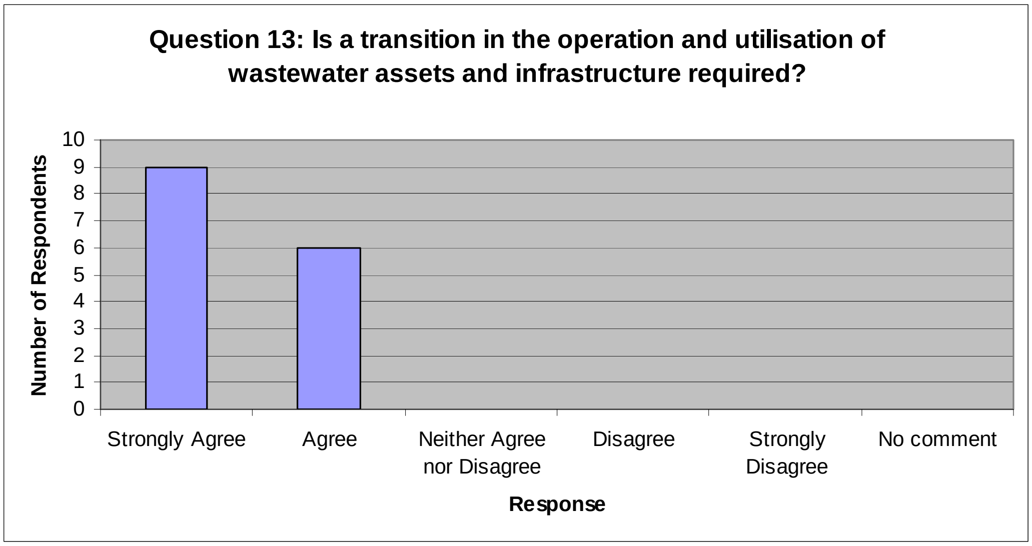

Question 10: Do you think removing surface water from customers properties through the disconnection rebate scheme is the 1st transitional step to achieving the vision of surface water free pumping stations?
Number of Respondents
8
7
6
5
4
3
2
1
0
Strongly Agree
Agree
Neither Agree nor Disagree
Disagree
Strongly Disagree
Response

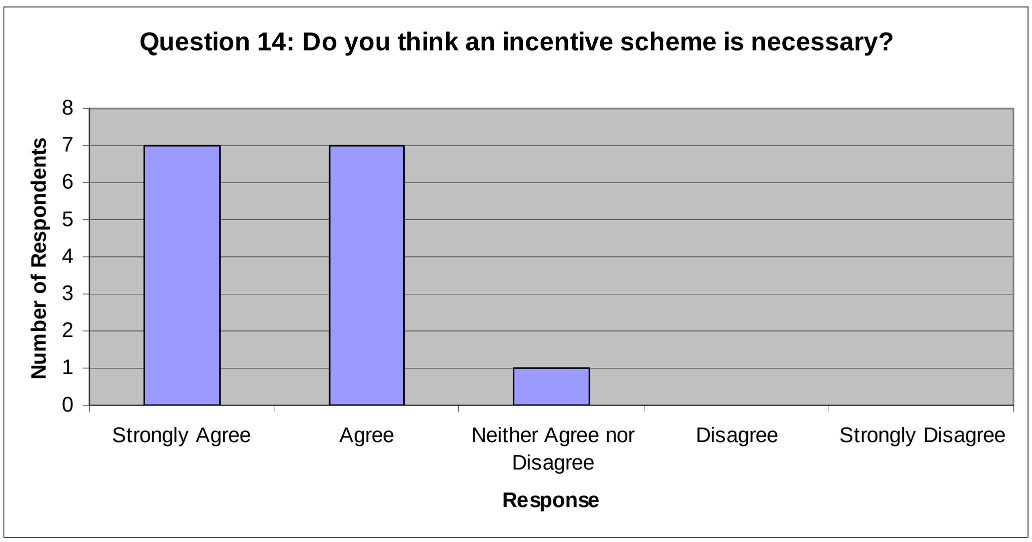

Question 11: Do you think the transitioning management cycle is the correct approach to achieve the vision of surface water free pumping stations?
Number of Respondents
10
9
8
7
6
5
4
3
2
1
0
Strongly Agree
Agree
Neither Agree nor Disagree
Disagree
Strongly Disagree
Response

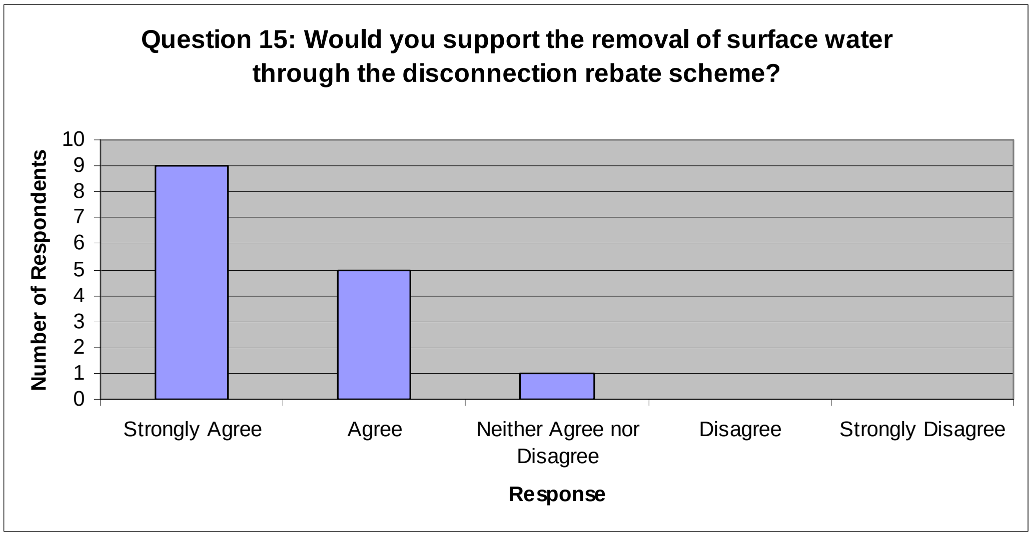


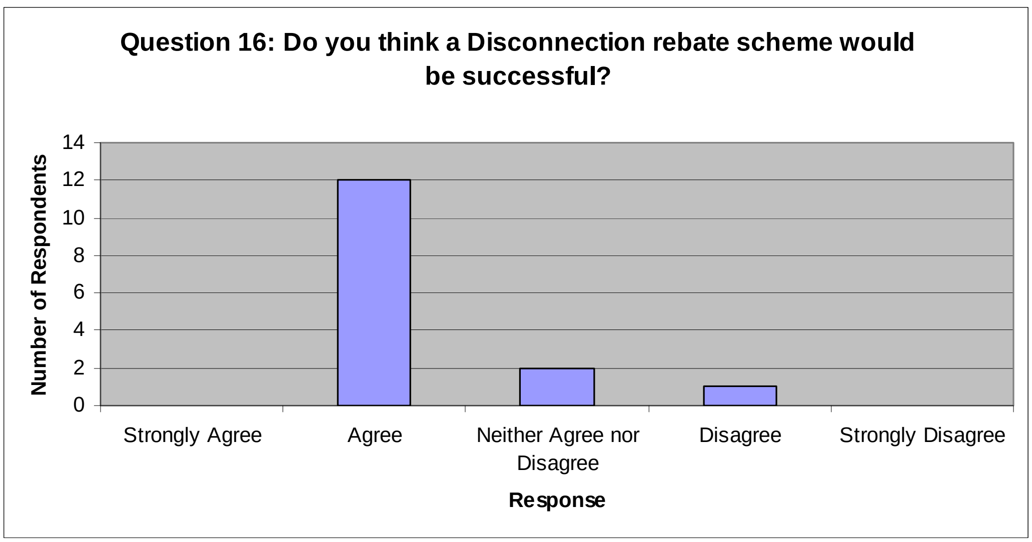
Question 12: Please rank the factors that would influence you the most in supporting a project removing the surface water flows from the combined sewer network?
Mode Information

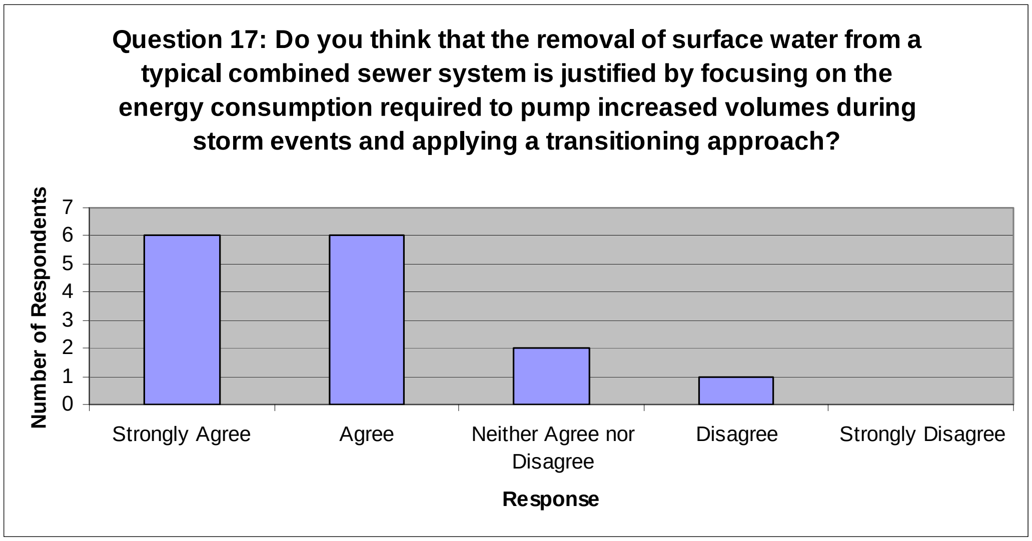
Influencing Factor	Responses received															TOTAL
Financial	2	3	4	2	3	1	1	6	2	1	1	1	5	4	1	99
Environmental	1	4	2	4	4	3	3	5	3	2	2	2	3	3	2	66
Legislation	4	2	1	1	2	2	2	7	1	5	5	4	1	5	5	67
Political	3	1	3	6	1	4	5	4	5	6	3	3	6	6	4	60
Health and Safety	5	5	5	3	5	5	6	3	6	4	6	5	2	1	6	47
Social	6	6	6	5	6	6	4	2	4	3	4	6	4	1	3	43

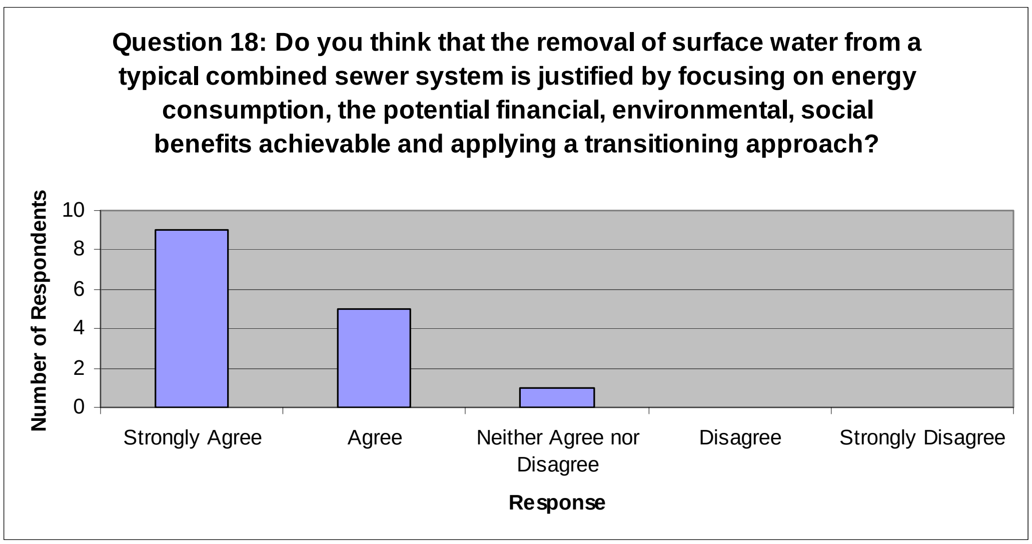

Question 13: Is a transition in the operation and utilisation of wastewater assets and infrastructure required?
Number of Respondents
0
1
2
3
4
5
6
7
8
9
10
Strongly Agree
Agree
Neither Agree nor Disagree
Disagree
Strongly Disagree
No comment
Response


Question 14: Do you think an incentive scheme is necessary?
Number of Respondents
0
1
2
3
4
5
6
7
8
Strongly Agree
Agree
Neither Agree nor Disagree
Disagree
Strongly Disagree
Response


Question 15: Would you support the removal of surface water through the disconnection rebate scheme?
Number of Respondents
10
9
8
7
6
5
4
3
2
1
0
Strongly Agree
Agree
Neither Agree nor Disagree
Disagree
Strongly Disagree
Response


Question 16: Do you think a Disconnection rebate scheme would be successful?
Number of Respondents
14
12
10
8
6
4
2
0
Strongly Agree
Agree
Neither Agree nor Disagree
Disagree
Strongly Disagree
Response


Question 17: Do you think that the removal of surface water from a typical combined sewer system is justified by focusing on the energy consumption required to pump increased volumes during storm events and applying a transitioning approach?
Number of Respondents
0
1
2
3
4
5
6
7
Strongly Agree
Agree
Neither Agree nor Disagree
Disagree
Strongly Disagree
Response


Question 18: Do you think that the removal of surface water from a typical combined sewer system is justified by focusing on energy consumption, the potential financial, environmental, social benefits achievable and applying a transitioning approach?
Number of Respondents
0
2
4
6
8
10
Strongly Agree
Agree
Neither Agree nor Disagree
Disagree
Strongly Disagree
Response

APPENDIX 3

SUDS Retrofit Financial Examination

Residential Rain Garden

CAPITAL COSTS

Site Name:
Site Location:
Date:

Choose Capital Costing Option

A	Total Facility Cost	$ 4,046

"A" - Simple Cost based on Drainage Area
"B" - User-Entered Engineer's Estimate

Installation type Chosen: Professional Installation — Single House

Method A: Simple Cost based on Drainage Area

Cost based on Drainage Area	Model Default		User	Chosen Option	
Drainage Area (DA) (Square Feet)		1076			1,076
Garden Area (Assumed 20% of DA, Square Feet)		215			215
Cost of Rain garden per Square Foot	$	16.05		$	16.05
Base Facility Cost of Rain garden	**$**	**3,454**		**$**	**3,454**
Landscape Design Costs	$	104		$	104
Resulting Base Cost of Rain garden (rounded up to nearest $10)	$	3,560		$	3,560
Establishment Costs, 1st year maintenance	$	488		$	488
Discount for Neighborhood Installations	$	-		$	-
Total Facility Cost	**$**	**4,046**		**$**	**4,046**

Method B: User-Entered Engineer's Estimate (Not applicable if self-installed)

Select from the following list, as applicable to the project or facility type; add items where necessary.

Total Facility Base Costs	Unit	Unit Cost	Quantity	Cost
Mobilization	LS			$ -
Clearing & Grubbing	AC			$ -
Excavation/Grading	CY			$ -
Dewatering	LS			$ -
Haul/Dispose of Excavated Material	CY			$ -
Sediment Pretreatment Struct.	LS			$ -
Impervious Lining	SY			$ -
Underdrain to Conventional Storm drain	LS			$ -
Soil Amendment, Engineered Medium Backfill	CY			$ -
Energy Dissipation Apron/ Inflow Structures	LS			$ -
Overflow Structure (concrete or rock riprap, optional)	CY			$ -
Landscaping Materials and Labor	SY			$ -
Other				$ -
Other				$ -
Other				$ -
Total Facility Base Cost				**$ -**
Associated Capital Costs	**Unit**	**Unit Cost**	**Quantity**	**Cost**
Landscape Design				$ -
Utility Relocation				$ -
Permitting & Construction Inspection				$ -
Sales Tax				$ -
Contingency (e.g., 30%)				$ -
Other				$ -
Other				$ -
Other				$ -
Total Associated Capital Costs				**$ -**
Total Facility Cost				**$ -**

Residential Rain Garden

Site Name:

Site Location:

Date:

M	**User entered 'MEDIUM' maintenance level in Sheet 1.**
P	**User entered 'Professional' installation type in Sheet 1.**
S	**User entered 'Single Home' installation type in Sheet 1.**

** Change on Sheet 1 if desired/applicable **

Maintenance Costs

User may enter lump sum here

ROUTINE MAINTENANCE ACTIVITIES (Frequent, scheduled events)																					
Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Incidentals Cost/Event ($)			Total cost per visit ($)		
	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input
Vegetation Management	12		12.0	2		2.00	2		2.0	31		31.00	0		0.00	10		10.00	134		134
add additional activities if necessary	0		0.0	0		0.00	0		0.0	0		0.00	0		0.00	0		0.00	0		0
add additional activities if necessary	0		0.0	0		0.00	0		0.0	0		0.00	0		0.00	0		0.00	0		0
CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or > 3 yrs. betw. events)																					
Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Incidentals Cost/Event ($)			Total cost per visit ($)		
	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input
Replace mulch	36		36.0	6		6.00	2		2.0	31		31.00	0		0.00	161		161.40	533		533
Till Soil	60		60.0	4		4.00	2		2.0	31		31.00	50		50.00	0		0.00	448		448
add additional activities if necessary	0		0.0	0		0.00	0		0	0		0.00	0		0.00	0		0.00	0		0
add additional activities if necessary	0		0.0	0		0.00	0		0.0	0		0.00	0		0.00	0		0.00	0		0

Note: For facilities judged to require larger or smaller amounts of maintenance (due to land area, etc.), consider multiplying the Model output in Column U by a multiplier (e.g., 120%) in Column V.
Another quick means of adjustment would be to multiply the number of Hours per Event by a multiplier in the User Input field.

Lookup Table Value

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
HIGH, MEDIUM, AND LOW (MINIMUM) MAINTENANCE COST TABLES																						
Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Incidentals Cost/Event ($)			Total cost per visit ($)			
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Self	Low	Med	High
ROUTINE MAINTENANCE ACTIVITIES (Frequent, scheduled)																						
Vegetation Management	36	12	1	0	2	2	0.0	2.0	3.0	0.00	31.00	45.00	0	0	60	0	10	20	10	0	134	410
add additional activities if necessary																				0	0	0
add additional activities if necessary																				0	0	0
CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or > 1 yrs. betw. events)																						
Replace mulch	60	36	12	4	6	8	2.0	2.0	2.0	0.00	31.00	45.00	0	0	0	161	161	161	161	161	533	881
Till Soil	120	60	48	4	4	4	2.0	2.0	2.0	0.00	31.00	45.00	50	50	50	0	0	0	50	200	448	560
add additional activities if necessary																				0	0	0
add additional activities if necessary																				0	0	0

Residential Rain Garden

Site Name:

Site Location:

Date:

M	User entered 'MEDIUM' maintenance level in Sheet 1.
P	User entered 'Professional' installation type in Sheet 1.
S	User entered 'Single Home' installation type in Sheet 1.
A	User entered 'Option A' Capital Cost Option in Sheet 2.

Cost Summary

CAPITAL COSTS	Total Cost		Included in WLC Calculation		
			Model	User	Chosen option
Base Cost of Garden (rounded up to nearest $100)		$ 3,454	$ 3,454		$ 3,454
Associated Capital Costs		$ 592	$ 592		$ 592
Capital Costs			$ 4,046		$ 4,046

REGULAR MAINTENANCE ACTIVITIES	months between events	Cost per Event	Total Cost per Year	Included in WLC Calculation		
				Model	User	Chosen option
Vegetation Management	12	$134	$134	$134		$ 134.00
add additional activities if necessary	0	$0	0	$0		$ -
add additional activities if necessary	0	$0	0	$0		$ -
Totals, Regular Maintenance Activities				**$134**		$ 134.00

CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or >3yrs. betw. events)	Years between Events	Cost per Event	Total Cost per Year Equivalent	Included in WLC		
				Model	User	Chosen option
Replace mulch	3	$533	$178	$178		$ 177.80
Till Soil	5	$448	$90	$90		$ 89.60
add additional activities if necessary	0	$0	$0	$0		$ -
Totals, Corrective & Infrequent Maintenance Activities				$267		$ 267.40

Residential Rain Garden

M	**User entered 'MEDIUM' maintenance level in Sheet 1.**
P	**User entered 'Professional' installation type in Sheet 1.**
S	**User entered 'Single Home' installation type in Sheet 1.**

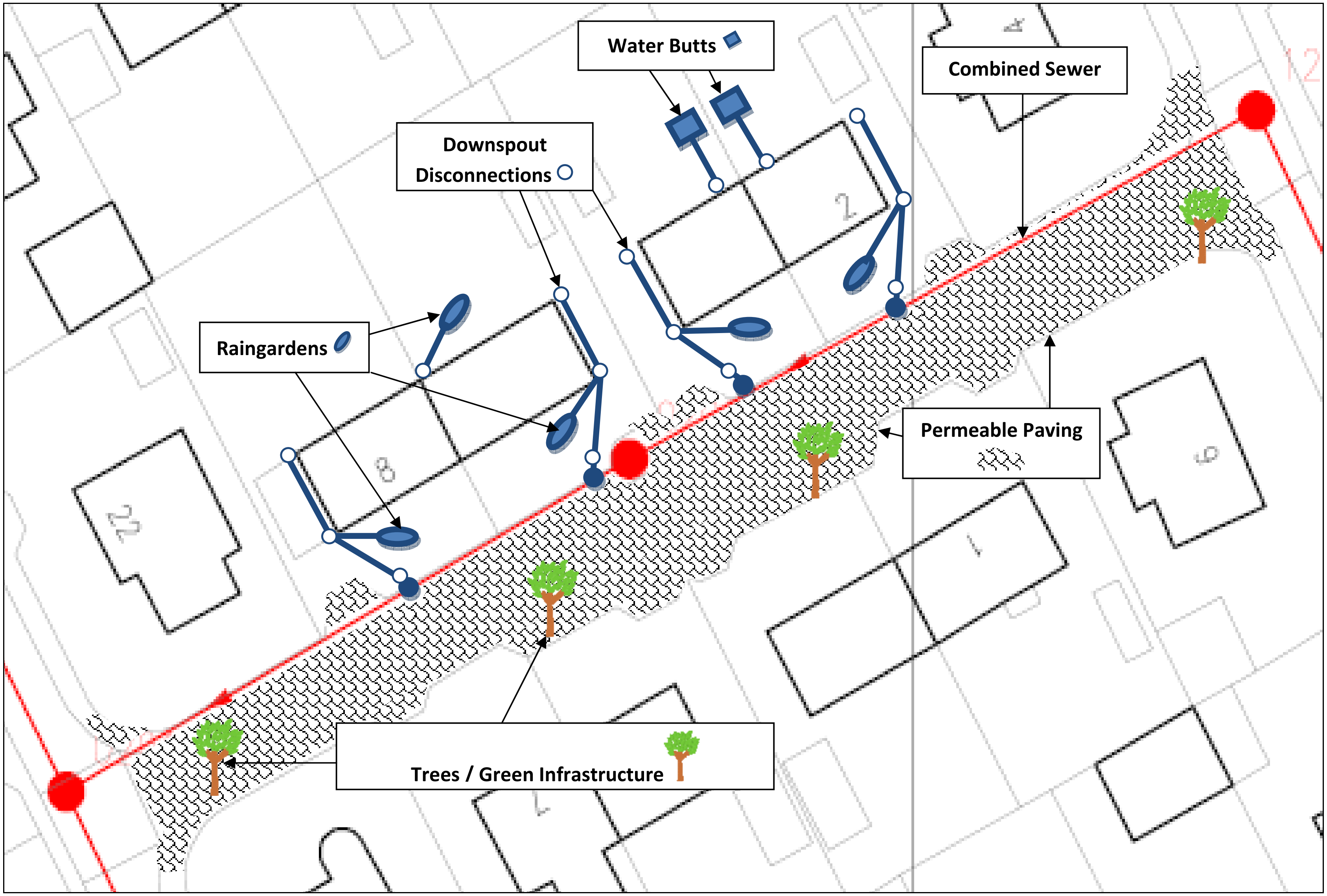
Site Name:

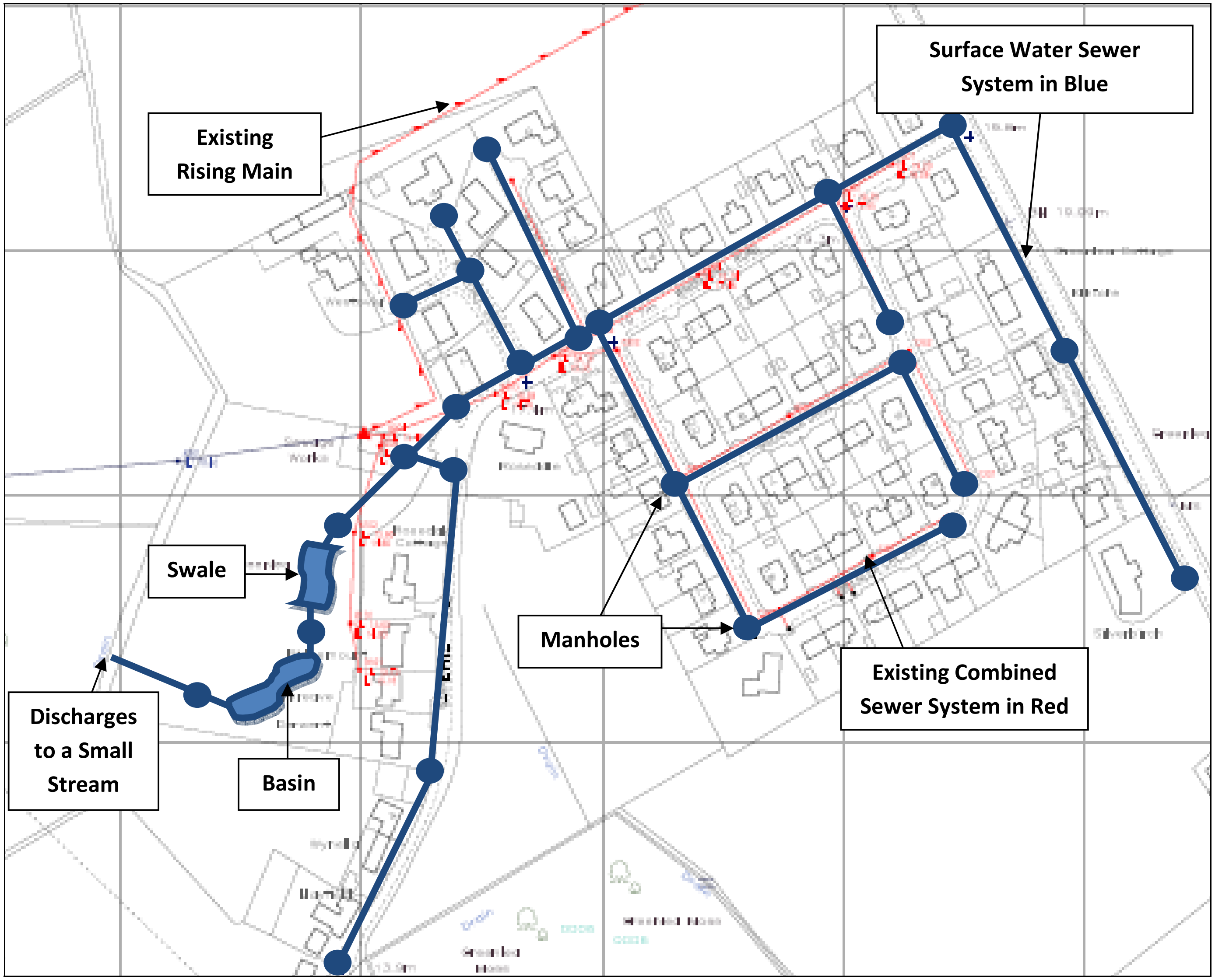
Site Location:

Date:

Whole Life Costs

Year	Discount Factor	Capital & Assoc. Costs	Regular Maint. Costs	Corrective Maint.	Total Costs	Present Value of Costs	Cumulative Costs		
							Cash	Present Value	Discounted Costs Per Year
Cash Sum ($)					**$ 23,894**	**$ 60,477**			
0	1.000	**$ 4,046**	$ 134		$ 4,180	$ 4,180	$ 4,180	$ 4,180	$ 60,477
1	1.036	$ -	$ 134	$ -	$ 134	$ 139	$ 4,314	$ 4,318	$ 56,297
2	1.074	$ -	$ 134	$ -	$ 134	$ 144	$ 4,448	$ 4,462	$ 56,158
3	1.113	$ -	$ 134	$ 533	$ 667	$ 743	$ 5,115	$ 5,205	$ 56,014
4	1.153	$ -	$ 134	$ -	$ 134	$ 155	$ 5,249	$ 5,360	$ 55,272
5	1.195	$ -	$ 134	$ 448	$ 582	$ 695	$ 5,831	$ 6,055	$ 55,117
6	1.238	$ -	$ 134	$ 533	$ 667	$ 826	$ 6,498	$ 6,881	$ 54,422
7	1.283	$ -	$ 134	$ -	$ 134	$ 172	$ 6,632	$ 7,053	$ 53,595
8	1.330	$ -	$ 134	$ -	$ 134	$ 178	$ 6,766	$ 7,232	$ 53,423
9	1.378	$ -	$ 134	$ 533	$ 667	$ 920	$ 7,434	$ 8,151	$ 53,245
10	1.428	$ -	$ 134	$ 448	$ 582	$ 831	$ 8,016	$ 8,982	$ 52,325
11	1.480	$ -	$ 134	$ -	$ 134	$ 198	$ 8,150	$ 9,181	$ 51,494
12	1.533	$ -	$ 134	$ 533	$ 667	$ 1,023	$ 8,817	$ 10,204	$ 51,296
13	1.589	$ -	$ 134	$ -	$ 134	$ 213	$ 8,951	$ 10,417	$ 50,273
14	1.647	$ -	$ 134	$ -	$ 134	$ 221	$ 9,085	$ 10,638	$ 50,060
15	1.706	$ -	$ 134	$ 981	$ 1,115	$ 1,903	$ 10,201	$ 12,541	$ 49,839
16	1.768	$ -	$ 134	$ -	$ 134	$ 237	$ 10,335	$ 12,778	$ 47,936
17	1.832	$ -	$ 134	$ -	$ 134	$ 246	$ 10,469	$ 13,024	$ 47,699
18	1.899	$ -	$ 134	$ 533	$ 667	$ 1,267	$ 11,136	$ 14,291	$ 47,453
19	1.968	$ -	$ 134	$ -	$ 134	$ 264	$ 11,270	$ 14,555	$ 46,186
20	2.039	$ -	$ 134	$ 448	$ 582	$ 1,187	$ 11,852	$ 15,741	$ 45,922
21	2.113	$ -	$ 134	$ 533	$ 667	$ 1,410	$ 12,519	$ 17,152	$ 44,735
22	2.190	$ -	$ 134	$ -	$ 134	$ 293	$ 12,653	$ 17,445	$ 43,325
23	2.269	$ -	$ 134	$ -	$ 134	$ 304	$ 12,787	$ 17,749	$ 43,032
24	2.351	$ -	$ 134	$ 533	$ 667	$ 1,569	$ 13,455	$ 19,319	$ 42,728
25	2.437	$ -	$ 134	$ 448	$ 582	$ 1,418	$ 14,037	$ 20,737	$ 41,158
26	2.525	$ -	$ 134	$ -	$ 134	$ 338	$ 14,171	$ 21,075	$ 39,740
27	2.617	$ -	$ 134	$ 533	$ 667	$ 1,746	$ 14,838	$ 22,822	$ 39,402
28	2.712	$ -	$ 134	$ -	$ 134	$ 363	$ 14,972	$ 23,185	$ 37,655
29	2.810	$ -	$ 134	$ -	$ 134	$ 377	$ 15,106	$ 23,562	$ 37,292
30	2.912	$ -	$ 134	$ 981	$ 1,115	$ 3,248	$ 16,222	$ 26,809	$ 36,915
31	3.018	$ -	$ 134	$ -	$ 134	$ 404	$ 16,356	$ 27,214	$ 33,667
32	3.127	$ -	$ 134	$ -	$ 134	$ 419	$ 16,490	$ 27,633	$ 33,263
33	3.240	$ -	$ 134	$ 533	$ 667	$ 2,163	$ 17,157	$ 29,795	$ 32,844
34	3.358	$ -	$ 134	$ -	$ 134	$ 450	$ 17,291	$ 30,245	$ 30,681
35	3.480	$ -	$ 134	$ 448	$ 582	$ 2,025	$ 17,873	$ 32,271	$ 30,231
36	3.606	$ -	$ 134	$ 533	$ 667	$ 2,407	$ 18,540	$ 34,677	$ 28,206
37	3.737	$ -	$ 134	$ -	$ 134	$ 501	$ 18,674	$ 35,178	$ 25,800
38	3.872	$ -	$ 134	$ -	$ 134	$ 519	$ 18,808	$ 35,697	$ 25,299
39	4.013	$ -	$ 134	$ 533	$ 667	$ 2,678	$ 19,476	$ 38,375	$ 24,780
40	4.158	$ -	$ 134	$ 448	$ 582	$ 2,420	$ 20,058	$ 40,795	$ 22,102
41	4.309	$ -	$ 134	$ -	$ 134	$ 577	$ 20,192	$ 41,372	$ 19,682
42	4.465	$ -	$ 134	$ 533	$ 667	$ 2,980	$ 20,859	$ 44,353	$ 19,104
43	4.627	$ -	$ 134	$ -	$ 134	$ 620	$ 20,993	$ 44,973	$ 16,124
44	4.795	$ -	$ 134	$ -	$ 134	$ 643	$ 21,127	$ 45,615	$ 15,504
45	4.969	$ -	$ 134	$ 981	$ 1,115	$ 5,542	$ 22,243	$ 51,158	$ 14,862
46	5.149	$ -	$ 134	$ -	$ 134	$ 690	$ 22,377	$ 51,848	$ 9,319
47	5.336	$ -	$ 134	$ -	$ 134	$ 715	$ 22,511	$ 52,563	$ 8,629
48	5.530	$ -	$ 134	$ 533	$ 667	$ 3,690	$ 23,178	$ 56,253	$ 7,914
49	5.730	$ -	$ 134	$ -	$ 134	$ 768	$ 23,312	$ 57,021	$ 4,224
50	5.938	$ -	$ 134	$ 448	$ 582	$ 3,456	$ 23,894	$ 60,477	$ 3,456


Water Butts
Combined Sewer
Downspout Disconnections
Raingardens
Permeable Paving
Trees / Green Infrastructure


Existing Rising Main
Surface Water Sewer System in Blue
Swale
Manholes
Existing Combined Sewer System in Red
Discharges to a Small Stream
Basin

Drainage Design

Road Hardstanding assume 10m width Roadway plus footway + 2.

Road Lengths

510m + 140m + 140m + 90m + 100m + 90m + 70m + 210m + 40m = 1390m.

1390m x 10m = 13,900m² Roadway Hardstanding.

Pre Development Runoff /Greenfield Runoff.

Flood Studies CNERC (1975) modified by IOH (1994).

Roadway only

Qbar = 0.00108 x AREA 0.89 x SAAR 1.17 x soil2.17

Total area of site = 25,935m^3 (Roads and Roofs)

Therefore Qbar / ha is 11.45 l/s/ha.

From flood study report Table 1 regional curve growth factor for:

1 year return period period = 0.85

2 year return period = 0.9

5 year return period period = 1.2

30 year return period period = 1.9

100 year return period period = 2.5

Therefore:

1year Greenfield Limiting Discharge = 0.85 x 15.37 = 13.06l/sec

2 year Greenfield Limiting Discharge = 0.9 x 15.37 = 13.83l/sec

5 year Greenfield Limiting Discharge = 1.2 x 15.37 = 18.44l/sec

30 year Greenfield Limiting Discharge = 1.9 x 15.37 = 29.20l/sec

100 year Greenfield Limiting Discharge = 2.5 x 15.37 = 38.42l/sec

Variable Depth Vt Calculation Sheet

SUDS Treatment Volume Vt, utilising CIRIA C697

Vt = 9 x D [soil / 2 + (1-soil / 2) x1] x (m^3 / Total Area in Hectare)

Variable Depth Method - D = Depth of Rainfall M5 – 60

Wallingford Maps M5 – 60 = 17

I = Impermeable => I =1

Wallingford Procedure (Winter acceptance potential Annual Average Rainfall)

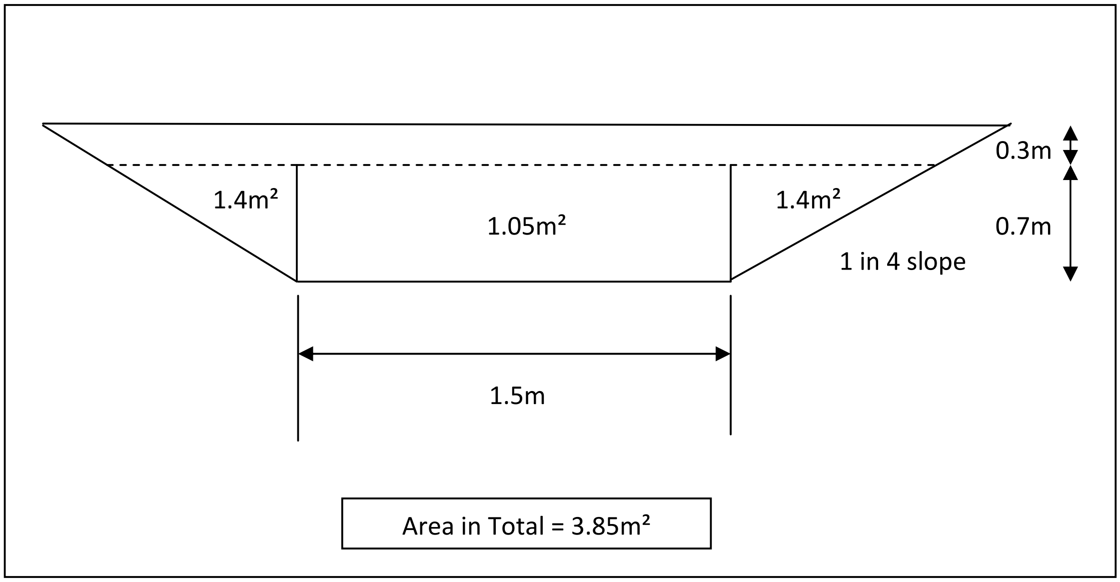
Soil = 0.45 For the Case Study drainage area.

Wallingford procedure Annual Average Rainfall SAAR = 1100

$$Vt = 9 \times 17\ (0.45 / 2) + (1 – (0.45/2) \times 1) \times 13900 / 10000$$

Vt **212.67m^3**

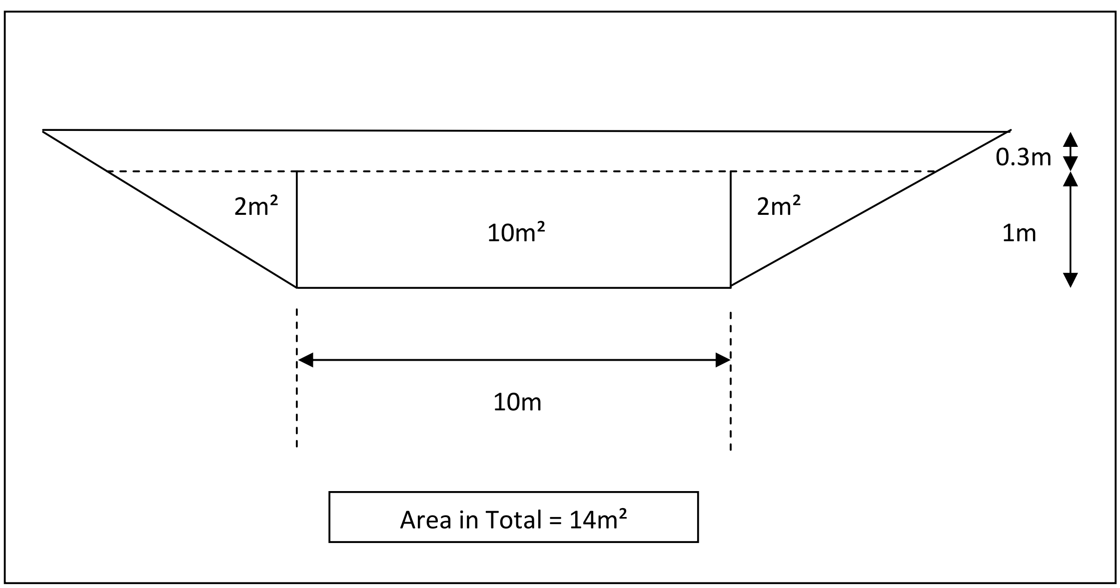
Swale Design



212.67m / 3.85m = 55.24m long swale provides 212.67m³ Storage

A Swale of average base width 1.5m, depth 1m including freeboard and length of 55.5 with 1 in 4 side sloped will provide a storage area of 212.67m3

Basin Design



212.67 / 14 = 15.19m. Basin Length = 15.19m

A Basin of average base width 10m and length of 15.5 and depth 1.m will provide a storage area of 217m3 with 1 in 4 side sloped.

General data

Project Overview

		Assumptions
Project name	Case Study	
Project description		
Location		
Location type		*This is for reference only - it is not used in the whole life cost analysis*
Date		
Option number		

Supporting financial information

		Assumptions
No. years for analysis	30	*Multiples of 10 years*
Discount rate - 0-30 yrs (%)	3.5%	
Discount rate - 31-75 yrs (%)	3.0%	
Discount rate - 75-125 yrs (%)	2.5%	*This is the Green Book's recommended discount rates*
Are land costs to be included?	No	
Estimated land costs of (£/m2)		
Land area of project (m2)		
Estimated land costs for SUDS	£ -	
Are easement costs to be included in the analysis?	No	
Estimated annual easement costs (£)		*Cost for total area, throughout life of analysis*
Planning and design costs (as % of construction costs)	0%	*Typically planning and design costs (for drainage) are calculated as a % of total construction costs. 3-5% is recommended for highways contracts, 5-10% is recommended for developments. For larger developments the % may be expected to be lower*
Do you want operation and maintenance to start on the same year as construction (year 0)?	No	*If the user selects no the tool will assume maintenance will commence in year 1 (NB year 0 is the construction year)*
Factor markup in prices since 2010 for construction costs (NB: cell automatically populated from cell D38 in step-by-step guide	1.00	*WLC tool was developed using 2010 prices. Please enter a factor markup in prices to adjust the default construction costs in the WLC tool (1.02 would equal 2% increase in costs since 2010), by using the calculations at the bottom of the step-by-step guide tab*
Factor markup in prices since 2010 for O&M costs (NB: NB: cell automatically populated from cell D45 in step-by-step guide	1.00	*WLC tool was developed using 2010 prices. Please enter a factor markup in prices to adjust the default construction costs in the WLC tool (1.02 would equal 2% increase in costs since 2010), by using the calculations at the bottom of the step-by-step guide tab*

Sensitivity analysis

		Assumptions
Will sensitivity analysis be carried out?	Yes	
If yes, please select confidence grade	A4	*Please see user guide for explanation of confidence grades (drop-down)*

Items to include in WLC analysis

No. levels of treatment	2	

Please select treatment(s):

		Quantity
Treatment 1	Swale	1
Treatment 2	Basins	1
Treatment 3		1

Go to Swale
Go to Basins

Is site set up and clearance to be included in this analysis?	No
Are pre-treatment and positive drainage to be included in the analysis?	No
Percentage of excavated material to be disposed off site	25%
What is the predominant soil type?	Sand & gravel soils

Assumptions

The tool allows up to three levels of treatment

Please select the levels of treatment from upstream to downstream. For Dry Swale, this is treated as one level of treatment

If multiple quantities of SUDS features are selected the tool will assume they have the same dimensions, and hence the same costs. All types of swales are considered to be one level of treatment

If selected yes, go to site set-up sheet. If the user selects no it is assumed that site set up costs have been included in separate whole life cost analysis

If selected yes, go to pre-treatment sheet

WRAP recommends 70-80% waste recovery on construction as best practice (therefore 20-30% disposed of off site). See www.wrap.org.uk

Excavation costs vary depending on the predominant soil type
- Sand and gravel soils - multiplied by factor of 1.0
- Stiff clay - multiplied by factor of 2.0
- Chalk - multiplied by factor of 3.0
- Soft & hard rock - multiplied by factor of 2.5

Catchment sediment

Total catchment area draining to SUDS (ha)	1.39
Sediment yield (kg/ha/yr)	1000
Density of sediment (kg/m3)	1200
Sediment removal efficiency of Swale	100%
Sediment removal efficiency of Basins	100%
Apply 50% reduction in sediment removal efficiency through the SUDS treatment train?	Y

Assumptions

User to enter the estimated catchment area draining to SUDS.

Approximate sediment yields:
- 200-500 kg/ha/yr for residential sites
- 350 kg/ha/yr for industrial/commercial sites
- 1000 kg/ha/yr for highway sites

Density of sediment from D'Arcy et al (2000) - 1200 kg/m3 is the mid-range

See user guidance for discussion on sediment removal rates for different SUDS features. If no data entered by user a default value of 50% is used (although no value will appear in cells C63-C65)

C609 recommends 50% reduction in removal efficiency for SUDS downstream of other SUDS features

Annual maintenance (for carbon calculation)

Assumptions

For all Ponds and Basins in this project

		Include maintenance for all ponds and basins, even if multiple numbers of them.
Vehicle used to go to site for maintenance		
Distance covered to site and back (km)		*1 mile = 1.609344 km*
Emissions per trip (kgCO_2e)	0.000	*Source of carbon emissions factor: Guidelines to Defra's GHG conversion factors for company reporting, Annexes Updated June 2007*
Any site plant used?		
Type of fuel used		
Fuel consumption per maintenance trip (per unit)		
Emissions per trip (kgCO_2e)	0	*Source of carbon emissions factor: Guidelines to Defra's GHG conversion factors for company reporting, Annexes Updated June 2007*
Number of trips per year		

If ponds and basins are maintained at the same time as the other SUDS features, split the distance between the two tables.

For all other SUDS features in this project

		Include maintenance for all other SUDS features, even if multiple numbers of them.
Vehicle used to go to site for maintenance		
Distance covered to site and back (km)		*1 mile = 1.609344 km*
Emissions per trip (kgCO_2e)	0.000	*Source of carbon emissions factor: Guidelines to Defra's GHG conversion factors for company reporting, Annexes Updated June 2007*
Any site plant used?		
Type of fuel used		
Fuel consumption per maintenance trip (per unit)		
Emissions per trip (kgCO_2e)	0	*Source of carbon emissions factor: Guidelines to Defra's GHG conversion factors for company reporting, Annexes Updated June 2007*
Number of trips per year		

Swale

Design parameters

Field	Units	Default	User defined	Values	Assumptions
Geometry					
Depth of swale (excluding underdrain)	m	0.5	1	1.00	
Depth range	m			1.0-2.0m	*The depth range is required for calculating the costs of excavation*
Side slope, S (1 in X) (max 1 in 4 recommended)	X	4.0		4.0	
Type of swale			1	1	*Choose type of the swale: "1" Simple conveyance swale, "2" Enhanced dry swale, "3" Enhanced wet swale (for further explanation of swale types see section 10.1 of the CIRIA C697 SUDS Manual*
Will swale be lined?	Y/N	N	Y	Y	
Width of swale	m		1.5	1.5	
Length of swale	m		55.5	55.5	
Freeboard	m	0.15	0.3	0.30	*0.15 recommended*
Landscaping					
Additional width around swale area for access/maintenance	m	0.0	1.5	1.5	
Underdrain (if dry swale selected)					
No. geotextile filters	nr	0		0	
Depth of sand filter layer	m				*0.9m is default depth. User can enter different value in cell E29 - volume will be automatically updated (in a hidden cell)*
Depth of pea gravel layer	m				
Length of PVCu perforated pipes	m	0		0	*Assume same as swale length. Only assume perforated pipes if type 2 swale selected*
Diameter of PVCu perforated pipes	mm				
Inlet/Outlet/Sediment control					
Will there be a point inflow to the swale (NB lateral sheet inflow is recommended)?	Y/N	N	Y	Y	
Number of inlets	nr	1	1	1	*Only assume inlets if point inlet structure selected*
Type of inlet structure			1	1	*Choose type of inlet structure: "1" Concrete headwall, "2" Bagwork headwall*
Will there be a gravel strip to control sheet inflow into the swale?	Y/N	Y	N	N	*Assume gravel strip is total length of swale. Only required if point inflow is not selected*
Width of the gravel strip to control sheet inflow	m			0	
Number of outlet structures	nr		1	1	
Type of outlet structure			1	1	*Choose type of outlet structure: "1" Concrete headwall, "2" Bagwork*
Number of silt trap structures	nr		0	0	
Number of check dams to control conveyance	nr		4	4	
Average length of each check dam	m	0.25	0.25	0.25	*Assume width is same as bottom width of swale, depth is half total swale height (not exceeding 90 cm)*

Capital cost (only enter data in fields if better data is available)

Field	Units	Quantity	Default cost per unit	User defined cost per unit	Capital cost	Cost Assumptions	Emission factor ($kgCO_2e$/unit)	Carbon emissions ($kgCO_2e$)	Carbon Assumptions and units
Excavation									
Excavating topsoil for preservation (300mm depth)	m3	130.12	£6.06		£789	*CESMM3 (2011) p.53 E3.1.1.01 excavation of topsoil + p.58 E.5.3.1.04 storage of topsoil on site*	2.80	364	*CESMM3 (2011) p.53 E3.1.1.01 excavation of topsoil + p.58 E.5.3.1.04 storage of topsoil on site*
Excavate remainder of site to reduce levels	m3	303.61	£3.27		£993	*CESMM3 (2011) p.53 E3.2.1.01 excavation in material other than topsoil, rock or artificial hard*	1.17	355	*CESMM3 (2011) p.53 E3.2.1.01 excavation in material other than topsoil, rock or artificial hard*
Deposition of excavated material off site									
Extra for carting excavated material off site to licensed tip	m3	75.90	£5.98		£454	*CESMM3 (2011) p.57 E5.3.1.01 disposal of topsoil, remove from site to tip, distance 5km*	3.40	258	*CESMM3 (2011) p.57 E5.3.1.01 disposal of topsoil, remove from site to tip, distance 5km*
Applying topsoil									
Spread and lightly consolidate topsoil brought from spoil heap	m2	627.07	£1.25		£784	*CESMM3 (2011) p.62 E6.4.1.10 filling with excavated topsoil taken from temporary stockpile 100m to depth 300mm*	0.77	483	*CESMM3 (2011) p.62 E6.4.1.10 filling with excavated topsoil taken from temporary stockpile 100m to depth 300mm*
Liner									
Liner to prevent infiltration	m2	384.67	£3.87		£1,491	*SPONS 2008 Ext Works, p270 'Lake Liners: Landline Ltd; Landflex or 'Alkorplan' geomembranes to prepared surfaces; all joints welded, (assumed 1.0m thick)'*	4.75	1,826	*assume PVC geomembrane (http://www.renolit.com/waterproofing-civil-engineering/en/applications/hydraulic-work/basins-and-similar-earthworks/); use 1.24g/cm3 @ 1.2mm thickness to convert = 1.488kg/m2 (example from Renolit ALKORPLAN 35254 - for hydraulic works). Emission factor for PVC is 3.19kgCO2/kg (ICEv2.0)*
Underdrain									
Sand filter media layer	m3	0.00	£17.05		£0	*SPONS 2008 Ext Works p262 'Market prices of backfilling materials SAND'*	11.20	0	*ICE v2.0 Sand emission factor 0.005kgCO2/kg, density 2240kg/m3*
Pea gravel layer	m2	0.00	£20.49		£0	*SPONS 2008 Ext Works, p144 'Bound aggregates… Golden Pea Gravel 1-3mm'*	2.70	0	*CESMM3 (2011) p.60 E6.1.5.01 2ype 1 imported granular material*
Geotextile filters	m2	0.00	£2.62		£0	*CESMM3 (2011) p.68 E7.3.1.02 Geotextile*	1.10	0	*CESMM3 (2011) p.68 E7.3.1.02 Geotextile*
Pipework									
Perforated PVCu pipes	m	0.00	£2.59		£0	*SPONS 2008 Ext Works p262, Wavin Plastics Ltd; flexible plastic perforated pipes in trenches (not included); plus couplings, to a min depth of 450mm; available in 35m coil (default, 160mm diameter). Cost for 225mm is 1.3 * cost for 160mm dia; Cost for 300mm is 1.8 * cost for 160mm*	7.95	0	*CESMM3 (2011) p.162-3 I5.1.2.01 PVC pipe, in trenches depth <1.5m. Diameters used are 100mm (for 80 and 100mm), 150mm (for 160mm), and 300mm (for 225 and 300).*

Inlet/Outlet/Control Structures									
Inlet structure (if point inflow selected)	total	1.00	£1,024.60		£1,025	*Bagwork headwall based on estimates from a project for Swindon Borough Council. Pre-cast concrete headwall figure from WERF. Latter estimate includes cost of safety grille*	88.35	88	*If concrete headwall, use penstock. For bagwork headwall use gate valve. CESMM3 Carbon and Price Book 2011, p186 'Hand operated gate valve, Flanged ductile iron valve, Nominal bore 80mm with cap'. p188 'Circular pattern cast iron penstock, Nomainal bore 100mm with cap.*
Outlet structure	total	1.00	£1,024.60		£1,025	*Bagwork headwall based on estimates from a project for Swindon Borough Council. Pre-cast concrete headwall figure from WERF. Latter estimate includes cost of trash screen*	88.35	88	*If concrete headwall, use penstock. For bagwork headwall use gate valve. CESMM3 Carbon and Price Book 2011, p186 'Hand operated gate valve, Flanged ductile iron valve, Nominal bore 80mm with cap'. p188 'Circular pattern cast iron penstock, Nomainal bore 100mm with cap.*
Gravel strip to control inflow to swale	m2	0.00	£20.49		£0	*SPONS 2008 Ext Works, p144 'Bound aggregates… Golden Pea Gravel 1-3mm'*	2.70	0	*CESMM3 (2011) p.60 E6.1.5.01 type 1 imported granular material*
Silt trap structure	nr	0.00	£155.72		£0	*SPONS Ext Works 2008 Vitrified clay intercepting trap, p249*	350.35	0	*CESMM3 (2011), p202 K3.1.1.01 'Vitrified clay road gully, 450mm dia x 900mm deep'*
Check dams	m3	0.75	£44.01		£33	*SPONS 2008 Ext Works, p137 'Type 1 granular fill base; PC £18.50/tonne (£40.70/m3 compacted) by machine, over 250mm thick'*	8.22	6	*CESMM3 (2011) E6.2.5.02 imported type 1 granular material to embankments*
Planting									
Supply and lay turf grass seed	m2	627.07	£0.28		£174	*SPONS 2008 Ext Works p169 & 172, 'Market price of grass seed British Seed Houses Ref A22 Low Maintenance; 25-35 g/m2' & Seeding labours only in operations by hand for 35 g/m2 & Raking over seeded areas by mechanical stone rake*	0.00	0	*CESMM3 (2011) p68, Seeding with grass seed*
Aquatic planting	nr	0.00	£2.52		£0	*SPONS 2008 Ext Works p205 Labour costs of 'Aquatic planting' & SPONS 2008 Ext Works p185 market price of aquatic plants Iris Pseudacorus & Assume 5 plants per m2*	0.00	0	*UK Building Blackbook (2011), p.383. No direct reference to aquatic plants but the UK Building Blackbook includes shrubs and hedging all listed as zero carbon (p.383)*
Watering & herbicides	ha	0.01	£1,133.45		£9	*SPONS 2008 Ext Works p61 Maintain planted area, control of weeds and grass, herbicide application 1.75mm centres*	10.00	0	*UK Building Blackbook (2011), Q302005A, p.382: Weedkiller by spreader, 0.03kg/m^2*

O&M cost

Field	Units	Default cost per unit	User defined cost per unit	Frequency - times per year	Cost per year	Data Source & Assumptions	Emission factor ($kgCO_2e$/unit)	Carbon emissions ($kgCO_2e$)	Carbon Assumptions and units
Annual maintenance									
Inspection and monitoring	nr	£63.47		12	£762	*SPONS Ext Works 2008 2 hours x labour rate plus vehicle costs (£18 per half day)*	Annual maintenance carbon emissions calculated from data at the bottom of the General tab		
Grass mowing (dispose off site)	/100m2	£1.48		4	£37	*SPONS Ext Works 2008 Page 214 self propelled rotary mower, 91cm cut width & Page 214 removing arisings not exceeding 30 deg from horizontal*			
Litter removal	/100m2	£0.87		12	£65	*SPONS Ext Works 2008 p216 collection and disposal of litter from isolated grassed area*			
Scrub clearance (dispose off site)	/100m2	£8.56		1	£47	*SPONS Ext Works 2008 p216 use rate for clearing leaf and other debris from verges by hand & p216 removal of arisings from areas containing trees and shrub beds*			
Periodic maintenance	**Units**	**Default cost per unit**	**User defined cost per unit**	**Frequency (in yrs)**	**Cost per activity**	**Data Source & Assumptions**	**Emission factor ($kgCO_2e$/unit)**	**Carbon emissions ($kgCO_2e$)**	**Carbon Assumptions and units**
Clear vegetation from swale & dispose of arisings off site	/100m	£1,738.47		5	£965	*SPONS Ext Works 2008 p256 Ditching clear only vegetation from ditch not exceeding 1.5m deep. Dispose to soil heaps width at top 2.5m to 4m & p216 Allow extra for disposal off site by truck. Use rate from page 216 for disposal of arisings from leaf clearance based on plan area of 1m length of swale - 4.5m 2 and a rate of £2.65/m2 typically if shallow as required in this guide. Deeper swales will be more expensive.*	19.76	11	*CESMM3 Carbon and Price Book 2011, p46 'Demolition and removal from site, wooded area', per ha 1317kgCO2/ha. Based on user defined swale width*
De-silting swale	/100m	£238.34		0	£132	*SPONS Ext Works 2008 p256 Ditching clear silt and bottom from ditch not exceeding 1.5m deep; strim back vegetation; disposing to spoil heaps; by machine. Assume 1.5-.25m wide at top*	175.50	97	*CESMM3 Carbon and Price Book 2011, p53 'Excavate material other than topsoil, rock or artificial hard material', per m3. Based on user defined width and depth*
Dispose silt off site	m3	£34.68		0	£2	*p105 Disposal; mechanical; Recycled Materials Ltd, for slightly contaminated*	3.40	4	*CESMM3 Carbon and Price Book 2011, p57 'Remove from site (transporting to top distance 5km)', per m3*

Capital maintenance (major refurbishment)

Field	Units	Default	User defined	Value to be used	Assumptions
What is the estimated design life of the SUDS (capital maintenance will be required at this point)	yrs	20	30	30	*Upper limit Life expectancy given in SR627*
Capital maintenance costs as % of initial construction costs	%	50%	0%	0%	

Basins

Design parameters

Field	Units	Default	User defined	Values	Assumptions
Geometry					
User entered volume of basin	m3			509	*Volume calculated by ((bottom area+top area)/2) * depth)*
Is the basin an infiltration basin?	Y/N		N	N	
Depth of basin	m	2.0	1.3	1.3	
Depth range	m			1.0-2.0m	*The depth range is required for calculating the costs of excavation*
Slope (max 1 in 4 recommended)	1 in x	4.0		4.0	
Length:width ratio	x	3.0	1.5	1.5	
Bottom width of basin	m		10.0	10.0	
Freeboard	m	0.30	0.30	0.30	
Landscaping					
Additional width around basin for access/maintenance	m	3.0	3.0	3.0	
Additional width around basin for amenity	m	2.0	1.0	1.0	
Additional width around basin for bankside vegetation	m	1.0	0.0	0.0	
Inlet					
Will there be an inlet channel to the basin?	Y/N		N	N	*Assume Y if infiltration basis, N if detention basir*
Length of inlet channel	m			0	
Width of inlet channel	m			0	
Depth of inlet channel	m			0	
Will there be a forebay?	Y/N		N	N	
Area of forebay (as % total area)	%			0	
Number of inlets	nr	0	1	1	
Type of inlet			1	1	*Choose type of inlet structure: "1" Concrete headwall, "2" Bagwork*
Outlet/sediment control					
Number of outlets	nr	0	1	1	
Type of outlet			1	1	*Choose type of outlet structure: "1" Concrete headwall, "2" Bagwork*
Number of silt trap structures	nr		0	0	
Overflow					
Will there be an overflow channel?	Y/N		Y	Y	
Length of overflow channel	m		2	2	
Width of overflow channel	m		1	1	
Depth of overflow channel	m		0.25	0.25	
Will overflow channel be grassed?	Y/N		Y	Y	*If not grassed then assume gravel filled. If grassed WLC model assumes some geotextile required to stabilise soil*

Capital cost (only enter data in fields if better data is available)

Field	Units	Quantity	Default cost per unit	User defined cost per unit	Capital cost	Cost Assumptions	Emission factor ($kgCO_2e$/unit)	Carbon emissions ($kgCO_2e$)	Carbon Assumptions and units
Excavation									
Excavating topsoil for preservation (300mm depth)	m3	117.58	£6.06		£713	*CESMM3 (2011) p.53 E3.1.1.01 excavation of topsoil + p.58 E.5.3.1.04 storage of topsoil on site*	2.80	329	*CESMM3 (2011) p.53 E3.1.1.01 excavation of topsoil + p.58 E.5.3.1.04 storage of topsoil on site*
Excavate remainder off site to reduce levels	m3	392.42	£3.27		£1,283	*CESMM3 (2011) p.53 E3.2.1.01 excavation in material other than topsoil, rock or artificial hard material*	1.17	459	*CESMM3 (2011) p.53 E3.2.1.01 excavation in material other than topsoil, rock or artificial hard material*
Deposition of excavated material off site									
Extra for carting excavated material off site to licensed tip	m3	97.98	£5.98		£586	*CESMM3 (2011) p.57 E5.3.1.01 disposal of topsoil, remove from site to tip, distance 5km*	3.40	333	*CESMM3 (2011) p.57 E5.3.1.01 disposal of topsoil, remove from site to tip, distance 5km*
Construction									
Construction of embankment to impound water (NB: assume embankment volume = width * depth * (length * 10%)	m3	82.40	£7.95		£655	*SPONS 2008 Ext Works, p96 'Embankments reinforced with Tensar Universal Geogrid ref 55 RE, 55 kN/m width, slopes not exceeding 45 degrees*	2.34	193	*CESMM3 (2011) p.60 E6.2.1.02 excavated topsoil taken from temporary stockpile 1286.99kgCO2/1000m3. Geogrid 0.33kg/m2 (http://www.tensarinternational.com/ss-geogrids.asp) ICEv2.0 PVC emission factor 3.19kgCO2/kg. Assume 1m2 geogrid per m3*
Construction of submerged berm (to isolate forebay) ((NB: assume embankment volume = width * depth * (length * 5%)	m3	41.20	£7.95		£328	*SPONS 2008 Ext Works, p96 'Embankments reinforced with Tensar Universal Geogrid ref 55 RE, 55 kN/m width, slopes not exceeding 45 degrees*	2.34	96	*CESMM3 (2011) p.60 E6.2.1.02 excavated topsoil taken from temporary stockpile 1286.99kgCO2/1000m3. Geogrid 0.33kg/m2 (http://www.tensarinternational.com/ss-geogrids.asp) ICEv2.0 PVC emission factor 3.19kgCO2/kg. Assume 1m2 geogrid per m3*
Applying topsoil									

Spread and lightly consolidate topsoil brought from spoil heap	m2	816.56	£1.25		£1,021	*CESMM3 (2011) p.62 E6.4.1.10 filling with excavated topsoil taken from temporary stockpile 100m to depth 300mm*	0.77	629	*CESMM3 (2011) p.62 E6.4.1.10 filling with excavated topsoil taken from temporary stockpile 100m to depth 300mm*
Liner									
Liner to prevent infiltration	m2	369.76	£3.87		£1,433	*SPONS 2008 Ext Works, p270 'Lake Liners: Landline Ltd; Landflex or 'Alkorplan' geomembranes to prepared surfaces; all joints welded, (assumed 1.0m thick)'*	4.75	1,755	*assume PVC geomembrane (http://www.renolit.com/waterproofing-civil-engineering/en/applications/hydraulic-work/basins-and-similar-earthworks/); use 1.24g/cm3 @ 1.2mm thickness to convert = 1.488kg/m2 (example from Renolit ALKORPLAN 35254 - for hydraulic works). Emission factor for PVC is 3.19kgCO2/kg (ICEv2.0)*
Planting									
Supply and lay turf grass seed	m2	816.56	£0.28		£226	*SPONS 2008 Ext Works p169 & 172, 'Market price of grass seed British Seed Houses Ref A22 Low Maintenance; 25-35 g/m2' & Seeding labours only in operations by hand for 35 g/m2 & Raking over seeded areas by mechanical stone rake*	0.00	0	*CESMM3 (2011) p68, Seeding with grass seed*
Bankside vegetation	nr	0.00	£2.33		£0	*SPONS 2008 Ext Works, p183 ' Market prices of trees, shrubs and plants Iris Foetidissama' 5 plants per m2*	0.00	0	*UK Building Blackbook (2011), p.383. No direct reference to aquatic plants but the UK Building Blackbook includes shrubs and hedging all listed as zero carbon (p.383)*
Gravel for overflow channel (if required)	m2	0.00	£20.49		£0	*SPONS 2008 Ext Works p144 'Bound aggregates… Golden Pea Gravel 1-3mm'*	2.70	0	*CESMM3 (2011) p.60 E6.1.5.01 type 1 imported granular material*
Inlet/Outlet/Control Structures									
Inlet structure (if point inflow selected)	total	1.00	£2,561.50		£2,562	*Bagwork headwall based on estimates from a project for Swindon Borough Council. Pre-cast concrete headwall figure from WERF. Latter estimate includes cost of safety grille*	88.35	88	*If concrete headwall, use penstock. For bagwork headwall use gate valve. CESMM3 Carbon and Price Book 2011, p186 'Hand operated gate valve, Flanged ductile iron valvle, Nominal bore 80mm with cap'. p188 'Circular pattern cast iron penstock, Nomainal bore*
Outlet structure	total	1.00	£2,561.50		£2,562	*Bagwork headwall based on estimates from a project for Swindon Borough Council. Pre-cast concrete headwall figure from WERF. Latter estimate includes cost of trash screen*	88.35	88	*bagwork headwall use gate valve. CESMM3 Carbon and Price Book 2011, p186 'Hand operated gate valve, Flanged ductile iron valvle, Nominal bore 80mm with cap'. p188 'Circular pattern cast iron penstock, Nomainal bore 100mm with cap.*
Silt trap structure	nr	0.00	£155.70		£0	*SPONS Ext Works 2008 Vitrified clay intercepting trap, p249*	350.35	0	*CESMM3 Carbon and Price Book 2011, p202 'Vitrified clay road gully, 450mm dia x 900mm deep'*

O&M cost

Field	Units	Default	User defined	Frequency - times per year	Cost per year	Data Source & Assumptions	Emission factor ($kgCO_2e$/unit)	Carbon emissions ($kgCO_2e$)	Carbon Assumptions and units
Annual maintenance									
Inspection and monitoring	nr	£63.47		12	£762	*SPONS Ext Works 2008 2 hours x labour rate plus vehicle costs (£18 per half day)*	Annual maintenance carbon emissions calculated from data at the bottom of the General tab		
Litter removal	/100m2	£0.87		12	£85	*SPONS Ext Works 2008 p216 collection and disposal of litter from isolated grassed area*			
Grass cutting in public areas	/100m2	£1.48		4	£26	*SPONS Ext Works 2008 Page 214 self propelled rotary mower, 91cm cut width & Page 214 removing arisings not exceeding 30 deg from horizontal*			
Grass cutting of meadow areas	/100m2	£1.48		2	£0	*SPONS Ext Works 2008 Page 214 self propelled rotary mower, 91cm cut width & Page 214 removing arisings not exceeding 30 deg from horizontal*			
Weed control	/100m2	£10.04		1	£82	*p217 hand weeding, established areas*			
Scrub clearance (dispose off site)	/100m2	£8.56		1	£70	*SPONS Ext Works 2008 p216 use rate for clearing leaf and other debris from verges by hand & p216 removal of arisings from areas containing trees and shrub beds*			
Periodic maintenance				**Frequency (in yrs)**	**Cost per activity**		**Emission factor ($kgCO_2$/unit)**	**Carbon emissions kg CO_2**	**Assumptions for carbon**
Scarify and spike base of basin	/100m2	£16.45		5	£25	*SPONS Ext Works 2008 Scarifying using pedestrian operated plant & dispose of arisings p215*		0	*Use transport emissions to site, as in General worksheet*
De-silting of forebay and dispose sediment off site	m3	£37.95		0	£0	*CESMM3 (2011) p.53 E3.2.1.01 excavation in material other than topsoil, rock or artificial hard material & SPONS 2008 Ext Works, p105 Disposal; mechanical; Recycled Materials Ltd, for slightly contaminated*	4.57	0	*CESMM3 Carbon and Price Book 2011, p53 'Excavate material other than topsoil, rock or artificial hard material', per m3 & CESMM3 Carbon and Price Book 2011, p57 'Remove from site (transporting to top distance 5km)'*
De-silting of main basin area and dispose sediment off site (only required where no forebay)	m3	£37.95		0	£0		4.57	0	

Capital maintenance (major refurbishment)

Field	Units	Default	User defined	Value to be used		Assumptions
What is the estimated design life of the SUDS (capital maintenance will be required at this point)	yrs	50	30	30		*Upper limit Life expectancy given in SR627*
Capital maintenance costs as % of initial construction costs	%	50%	0%	0%		

SUDS FOR ROADS WHOLE LIFE COST TOOL

Whole Life Cost Analysis Results

Summary Information

Project name:	Case Study
Location:	0
Location type:	0
Date:	00/01/1900
No. treatment levels:	2
Pre-treatment included:	No
No. years analysis:	30

Results - not cumulative

		Years						Total Whole Life Costs
		0	**1-5**	**6-10**	**11-20**	**21-50**	**51-99**	
Swale	Annual maintenance	£0	£4,112	£3,462	£5,370	£3,482	£0	
	Periodic maintenance	£0	£812	£684	£1,061	£408	£0	
	Capital maintenance	£0	£0	£0	£0	£0	£0	
	Construction	£6,775	£0	£0	£0	£0	£0	
	Total Swale	£6,775	£4,925	£4,146	£6,431	£3,891	£0	**£26,167**
Basins	Annual maintenance	£0	£4,627	£3,896	£6,042	£3,918	£0	
	Periodic maintenance	£0	£21	£17	£27	£10	£0	
	Capital maintenance	£0	£0	£0	£0	£0	£0	
	Construction	£11,367	£0	£0	£0	£0	£0	
	Total Basins	£11,367	£4,647	£3,913	£6,069	£3,928	£0	**£29,925**
	Annual maintenance	£0	£0	£0	£0	£0	£0	
	Periodic maintenance	£0	£0	£0	£0	£0	£0	
	Capital maintenance	£0	£0	£0	£0	£0	£0	
	Construction	£0	£0	£0	£0	£0	£0	
	Total	£0	£0	£0	£0	£0	£0	**£0**
Pre-treatment	Periodic maintenance	£0	£0	£0	£0	£0	£0	
	Capital maintenance	£0	£0	£0	£0	£0	£0	
	Construction	£0	£0	£0	£0	£0	£0	
	Total pre-treatment	£0	£0	£0	£0	£0	£0	**£0**
Other costs	Land, design, site set-up	£0	£0	£0	£0	£0	£0	**£0**
	Easement costs	£0	£0	£0	£0	£0	£0	**£0**
Total Costs		£18,142	£9,572	£8,059	£12,499	£7,819	£0	**£56,092**

Total WLC	**£56,092**

Swale
Basins
0
No

Associated Pipework

Basin Construction Costs	Length	Unit	Cost	Construction Cost	Reference
150mm Pipework	700	m	£51.34	£35,938.00	CESMME 3 Carbon and PrIce Book 2011 p162. In trench depth 1.5m unplasticed PVC pipes BS EN 1 452 and BS 3506, Class "C" 6m lengths; compression joints with rubbber rings, Normal bore 150mm
150mm Pipework	510	m	£56.53	£28,830.30	CESMME 3 Carbon and PrIce Book 2011 p162. In trench depth 1.5-2.0m unplasticed PVC pipes BS EN 1 452 and BS 3506, Class "C" 6m lengths; compression joints with rubbber rings, Normal bore 150mm
225mm Pipework	160		56.58	£9,052.80	CESMME 3 Carbon and PrIce Book 2011 p163. In trench depth 1.5-2m unplasticed PVC pipes BS EN 1 452 and BS 3506, Class "C" 6m lengths; compression joints with rubbber rings, Normal bore 300mm
375mm Pipework	60		151.42	£9,085.20	CESMME 3 Carbon and PrIce Book 2011 p163. In trench depth 1.5-2m unplasticed PVC pipes BS EN 1 452 and BS 3506, Class "C" 6m lengths; compression joints with rubbber rings, Normal bore 300mm
	1430				
Manhole 1.5 deep	21	Item	£1,644.65	£34,537.65	CESMM3 Carbon and Price Book 2011 p197, Precast concrete manhole 1200mmx1200mm normal internal diameter manhole ring depth 1.5m
Manhole 2m deep	7	Item	1891.21	£13,238.47	CESMM3 Carbon and Price Book 2011 p197, Precast concrete manhole 1200mmx1200mm normal internal diameter manhole ring depth 2m
		Total Cost		**£130,682.42**	

Permeable Pavement

Site Name:

Site Location:

Design & Maintenance Options

WATERSHED CHARACTERISTICS	Unit	Model Default	User	Chosen option
Surface Area of Permeable Pavement System	ft2	21,780	25,700	25,700
Drainage Area (DA)	ft2	21,780	25,700	25,700
Drainage Area Impervious Cover (IC)*	pct	100%	100.0%	100%
Watershed Land Use Type *("R"-Residential; "C"-Commercial; "Ro"-Roads; "I"-Industrial)*		R	Ro	Ro

* Included since frequently used to calculate facility sizing.

DESIGN & MAINTENANCE OPTIONS	Unit	Model Default	User	Chosen Option
Choose among the following (affects default cost calcs):	-	1	4	4
1. Asphalt	User Selected Pavement Type = **Interlocking Concrete Paving Blocks**			
2. Porous Concrete				
3. Grass / Gravel Pavers				
4. Interlocking Concrete Paving Blocks				
5. Other				
Choose Capital Cost Level *("H"=high; "L"=low)*	-	H	H	H
Choose Level of Maintenance *("H"=high; "M"=medium; "L"=low)*	-	L	L	L

WHOLE LIFE COST OPTIONS	Unit	Model Default	User	Chosen Option
Discount Rate	%	5.50	3.5	3.5

Permeable Pavement

CAPITAL COSTS

Site Name:

Site Location:

Choose Capital Costing Option

A	Total Facility Cost	$ 339,300

"A" - Simple Cost based on System Type

"B" - User-Entered Engineer's Estimate

Method A: Simple Cost based on Drainage Area

Cost based on Drainage Area	Cost per Acre of DA Treated		(Chosen option)
	Model Default	User	
User Selected **INTERLOCKING CONCRETE PAVING BLOCKS** Permeable Paveme		Entered Sheet 1	4
Surface Area of Permeable Pavement System (ft2)		Entered Sheet 1	25,700
User Selected HIGH Permeable Pavement		Entered Sheet 1	H
Permeable Pavement Cost per square foot	$10.00	$10.00	$10.00
Base Facility Cost (rounded up to nearest $100)	$ 257,000	$ 257,000	**$ 257,000**
Engineering & Planning (default = 10% of Base Cost)	$ 25,700	$ 25,700	$ 25,700
Land Cost	$ 0		$ 0
Other Costs	$ 0		$ 0
Contingency (default = 20%, rounded up to nearest $100)	$ 56,600	$ 56,600	$ 56,600
Total Associated Capital Costs (e.g., Engineering, Land, etc.)			**$ 82,300**
Total Facility Cost	**$ 282,700**		**$ 339,300**

Suggestion: Use higher or lower Per Unit Costs to reflect higher or lower regional construction costs.

Method B: User-Entered Engineer's Estimate

Select from the following list, as applicable to the project or facility type; add items where necessary.

Total Facility Base Costs	Unit	Unit Cost	Quantity	Cost
Mobilization	LS			$ -
Clearing & Grubbing	AC			$ -
Excavation/Grading	CY			$ -
Haul/Dispose of Excavated Material	CY			$ -
Subsoil Preparation	SY			$ -
Impermeable Liner	SY			$ -
Rock Media	SY			$ -
Permeable Media	SF			$ -
Outflow Structure/Pipe	LS			$ -
Energy Dissipation Apron	LS			$ -
Revegetation/Erosion Controls	SY			$ -
Traffic Control	LS			$ -
Signage, Public Education Materials, etc.	LS			$ -
Other				$ -
Other				$ -
Total Facility Base Cost				**$ -**
Associated Capital Costs	**Unit**	**Unit Cost**	**Quantity**	**Cost**
Project Management				$ -
Engineering: Preliminary				$ -
Engineering: Final Design				$ -
Topographic Survey				$ -
Geotechnical				$ -
Landscape Design				$ -
Land Acquisition (site, easements, etc.)				$ -
Utility Relocation				$ -
Legal Services				$ -
Permitting & Construction Inspection				$ -
Sales Tax				$ -
Contingency (e.g., 30%)				$ -
Total Associated Capital Costs				**$ -**
Total Facility Cost				**$ -**

Permeable Pavement

Site Name:
Site Location:

Cost Summary

CAPITAL COSTS	Included in WLC Calculation			Total Cost	
	Model	User	Chosen option		
Total Facility Base Cost	Y	Y	Y		$257,000
Total Associated Capital Costs (e.g., Engineering, Land, etc.)	Y	Y	Y		$25,700
Capital Costs	Y	Y	Y		**$339,300**

REGULAR MAINTENANCE ACTIVITIES	Included in WLC Calculation			Years between Events	Cost per Event	Total Cost per Year
	Model	User	Chosen option			
Inspection, Reporting & Information Management	Y	Y	Y	3	$90	$30
Litter & Minor Debris Removal	Y	Y	Y	3	$45	$15
Permeable pavement sweeping	Y	Y	Y	3	$160	$53
Additional activities	Y	Y	Y	0	$0	$0
Additional activities	Y	Y	Y	0	$0	$0
Totals, Regular Maintenance Activities						**$98**

CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or >3yrs. betw. events)	Included in WLC			Years between Events	Cost per Event	Total Cost per Year
	Model	User	Chosen option			
Intermittent facility maintenance	Y	Y	Y	0	$0	$0
Remove existing pavement & aggregate; wash and/or replace & reinstall*	Y	Y	Y	45	$257,000	$5,711
Additional activities	Y	Y	Y	0	$0	$0
Additional activities	Y	Y	Y	0	$0	$0
Totals, Corrective & Infrequent Maintenance Activities						**$5,711**

Permeable Pavement

Site Name:
Site Location:

Whole Life Costs

Year	Discount Factor	Capital & Assoc. Costs	Regular Maint. Costs	Corrective Maint.	Total Costs	Present Value of Costs	Cumulative Costs	
							Cash	Present Value
Cash Sum ($)					**$ 341,758**	**$ 340,921**		
0	1.000	**$ 339,300**			$ 339,300	$ 339,300	$ 339,300	$ 339,300
1	0.966	$ -	**$ 98**	$ -	$ 98	$ 95	$ 339,398	$ 339,395
2	0.934	$ -	$ 98	$ -	$ 98	$ 92	$ 339,497	$ 339,487
3	0.902	$ -	$ 98	$ -	$ 98	$ 89	$ 339,595	$ 339,575
4	0.871	$ -	$ 98	$ -	$ 98	$ 86	$ 339,693	$ 339,661
5	0.842	$ -	$ 98	$ -	$ 98	$ 83	$ 339,792	$ 339,744
6	0.814	$ -	$ 98	$ -	$ 98	$ 80	$ 339,890	$ 339,824
7	0.786	$ -	$ 98	$ -	$ 98	$ 77	$ 339,988	$ 339,901
8	0.759	$ -	$ 98	$ -	$ 98	$ 75	$ 340,087	$ 339,976
9	0.734	$ -	$ 98	$ -	$ 98	$ 72	$ 340,185	$ 340,048
10	0.709	$ -	$ 98	$ -	$ 98	$ 70	$ 340,283	$ 340,118
11	0.685	$ -	$ 98	$ -	$ 98	$ 67	$ 340,382	$ 340,185
12	0.662	$ -	$ 98	$ -	$ 98	$ 65	$ 340,480	$ 340,250
13	0.639	$ -	$ 98	$ -	$ 98	$ 63	$ 340,578	$ 340,313
14	0.618	$ -	$ 98	$ -	$ 98	$ 61	$ 340,677	$ 340,374
15	0.597	$ -	$ 98	$ -	$ 98	$ 59	$ 340,775	$ 340,433
16	0.577	$ -	$ 98	$ -	$ 98	$ 57	$ 340,873	$ 340,489
17	0.557	$ -	$ 98	$ -	$ 98	$ 55	$ 340,972	$ 340,544
18	0.538	$ -	$ 98	$ -	$ 98	$ 53	$ 341,070	$ 340,597
19	0.520	$ -	$ 98	$ -	$ 98	$ 51	$ 341,168	$ 340,648
20	0.503	$ -	$ 98	$ -	$ 98	$ 49	$ 341,267	$ 340,698
21	0.486	$ -	$ 98	$ -	$ 98	$ 48	$ 341,365	$ 340,745
22	0.469	$ -	$ 98	$ -	$ 98	$ 46	$ 341,463	$ 340,791
23	0.453	$ -	$ 98	$ -	$ 98	$ 45	$ 341,562	$ 340,836
24	0.438	$ -	$ 98	$ -	$ 98	$ 43	$ 341,660	$ 340,879
25	0.423	$ -	$ 98	$ -	$ 98	$ 42	$ 341,758	$ 340,921

UKWIR WM/07: Exploring the cost-benefit of separating direct surface water inputs from the combined sewerage system

DECISION SUPPORT TOOL DATA CAPTURE PROFORMA

Please complete grey boxes. Only enter numeric values.

Please enter data for Sections 1 and 2 where appropriate.

Location:	South Collin
Scheme ID:	Sheet to be completed separately for each scheme

1. Please quantify intervention measures included in the scheme:

1.1 Conventional measures based on upgrading the sewerage network	
Sewer upsizing/ duplication	New combined sewer overflow
New or replacement pumping station	Individual property isolation
Flow attenuation	Isolate area
Pumping station upsizing	Upgrading WwTW FFT capacity
Flow diversion	Other measures
1.2 Alternative measures based on disconnection from the sewerage network:	
1.2.1 Domestic foul	1.2.5 Industrial/institutional/retail/commercial runoff
1.2.2 Domestic runoff	1.2.6 Highway runoff
1.2.3 Domestic (new build)	1.2.7 Land drainage/watercourses/land runoff/surface sewers
1.2.4 Industrial/institutional/retail/commercial foul	1.2.8 Other measures

2. Please quantify benefits/dis-benefits avoided from the scheme

3. Summary

3.5%	**Discount rate used**
25	**Assessment period (years)**
All values in 2009 prices	

SECTION 1: INTERVENTION MEASURES INCLUDED IN THE SCHEME

1.1 Conventional measures based on upgrading the sewerage network		
Sewer upsizing/ duplication		Capital cost in pounds
		Maintenance cost in pounds per year
and		Length of new sewer in metres
New or replacement pumping station		Capital cost in pounds
		Maintenance cost in pounds per year
		Increase in sewage pumping in kilowatt hours per year
Flow attenuation (and storm tank detention basins)		Capital cost in pounds
		Maintenance cost in pounds per year
Pumping station – mechanical/electrical upsizing		Capital cost in pounds
		Maintenance cost in pounds per year
		Increase in sewage pumping in kilowatt hours per year
Flow diversion (local or catchment)		Capital cost in pounds
		Maintenance cost in pounds per year
New combined sewer overflow (CSO)		Capital cost in pounds
		Maintenance cost in pounds per year
Individual property isolation (by non-return valve or by pumping station)		Capital cost in pounds
		Maintenance cost in pounds per year
Isolate area (provide pumping station)		Capital cost in pounds
		Maintenance cost in pounds per year
		Increase in sewage pumping in kilowatt hours per year
Upgrading WwTW FFT capacity		Capital cost in pounds
		Maintenance cost in pounds per year
		Increase in flow treated in cubic metres per year

Other measures		

1.2 Alternative measures based on disconnection from the sewerage network

1.2.1 Domestic foul

Reduction in per capita consumption		Volume reduced in cubic metres per year

1.2.2 Domestic runoff

Foul/ surface separation - new sewer	**130,682**	Capital cost in pounds
	0	Maintenance cost in pounds per year
and	**1,430**	Length of new surface sewer in metres
Green roofs		Cost of measure in pounds (as PV)
Bio-retention areas	**1,797**	Area of measure in square metres
Swales	**83**	Area of measure in square metres
Balancing ponds		Volume of measure in cubic metres
Detention basins	**214**	Volume of measure in cubic metres
Soakaways		Area of measure in square metres
Infiltration basin		Volume of measure in cubic metres
Filter strips		Area of measure in square metres
Filter drains		Length of measure in metres
Sand filters		Area of measure in square metres
Rainwater harvesting	**3,056**	Cost of measure in pounds (as PV)
Constructed wetlands		Volume of measure in cubic metres
Pervious surfaces		Area of measure in square metres

1.2.3 Domestic new-build

Foul/ surface separation - new sewer		Capital cost in pounds
		Maintenance cost in pounds per year
and		Length of new surface sewer in metres

1.2.4 Industrial/institutional/retail/commercial foul

Increase in water efficiency		Volume reduced in cubic metres per year

1.2.5 Industrial/institutional/retail/commercial runoff

Foul/ surface separation - new sewer		Capital cost in pounds
		Maintenance cost in pounds per year
and		Length of new surface sewer in metres
Reuse		Cost of measure in pounds (as PV)
Green roofs		Cost of measure in pounds (as PV)
Bio-retention areas		Area of measure in square metres
Swales		Area of measure in square metres
Balancing ponds		Volume of measure in cubic metres
Detention basins		Volume of measure in cubic metres
Soakaways		Area of measure in square metres
Infiltration basin		Volume of measure in cubic metres

Filter strips		Area of measure in square metres
Filter drains		Length of measure in metres
Sand filters		Area of measure in square metres
Rainwater harvesting		Cost of measure in pounds (as PV)
Constructed wetlands		Volume of measure in cubic metres
Pervious surfaces		Area of measure in square metres

1.2.6 Highway runoff

Separation - new drain and outfall		Cost of new Highways drain in pounds (as PV)
and		Length of new Highways drain in metres
Infiltration (e.g. swales, filter strips, soakaways)		Area of measure in square metres
Detention (e.g. balancing ponds, detention basins)		Volume of measure in cubic metres

1.2.7 Land drainage/watercourses/land runoff/surface sewers

Land drainage separation - new drain and outfall		Cost of new drain in pounds (as PV)
and		Length of new drain in metres
Watercourse separation - new sewer		Capital cost in pounds
		Maintenance cost in pounds per year
and		Length of new surface sewer in metres
Watercourse separation - river restoration		Cost of measure in pounds (as PV)
Surface sewer separation - new sewer		Capital cost in pounds
		Maintenance cost in pounds per year
and		Length of new surface sewer in metres

1.2.8 Other measures

SECTION 2: BENEFITS FROM THE SCHEME (OR DIS-BENEFITS AVOIDED)

2.1 Willingness to Pay		
2.1.1 Reduction in properties subject to internal flooding from sewage		Number of properties with reduced flooding risk
		Typical benefit value in pounds per property affected per year
2.1.2 Reduction in properties subject to external flooding from sewage		Number of properties with reduced flooding risk
		Typical benefit value in pounds per property affected per year
2.1.3 River water quality improvements		Length of river benefited in kilometres
		Typical benefit value in pounds per km improved per year
2.1.4 Bathing water quality improvements		Number of Bathing Waters improved
		Typical benefit value in pounds per Bathing Water improved per year
2.1.5 Other benefits		

2.2 Energy reduction and carbon abatement		
2.2.1 Reduction in wastewater treatment	**16,550**	Reduction in wastewater flow treated in cubic metres per year

	1	Typical cost of wastewater treatment in pounds per cubic metre
2.2.2 Reduction in sewage pumping	**230**	Reduction in sewage pumping in kilowatt hours per year
	0.1	Typical cost of electricity in pounds per kilowatt hour

SECTION 3: SUMMARY

Financial cost	Present value	**£487,717**	
E&S cost	Present value	**£553**	
Financial costs avoided	Present value		
E&S costs avoided	Present value		
Overall benefit	Present value	**£386,971**	
Total cost-benefit	**Net Present Value**	**-£101,298**	
Annual carbon emissions (monetised above)	tonnes CO_2e per year	**-12**	(negative value is a saving)

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